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bilobed, posterolateral corners rounded; mesonotum and metanotum narrower than pronotum, their posterior borders slightly concave; wing stumps subequal in size, anterior ones overlapping base of posterior; wings hyaline, costal margin yellowish, veins yellowish at base; wing membrane densely beset with minute hairs, radius nerve of anterior wing parallel to costal margin; median nerve faint, nearer to cubitus than to radius, with no branch; cubitus below middle of wing, not reaching tip, with about seven branches, of which the proximal four are stronger; median nerve of posterior wing starts from proximal portion of radius.

Measurements of the imago.

	mm.
Length of body with wings	14.00
Length of body without wings	6.00
Length of head	1.40
Width of head	1.31
Width of pronotum	1.31
Length of pronotum	0.87
Length of anterior wing	11.00

Queen.—Head and thorax similar to those of imago; mesonotum and metanotum with a pair of triangular wing stumps; abdomen much enlarged; abdominal tergites pale reddish brown, separated from each other by a distance about four times as great as its length; abdominal integument milk white.

Measurements of the queen.

	mm.
Length of body	21.00
Length of abdomen	19.00
Width of abdomen	5.50

King.—All the characters agree very well with those of the imago; abdomen not enlarged; thorax provided with two pairs of triangular wing stumps.

Substitute queen.—Head yellow; postclypeus somewhat paler; anteclypeus whitish; mandibles pale yellow, with brown tips; antennæ and legs pale yellow; thoracic plates yellow; abdomen milk white, with pale yellow abdominal tergites; head and thoracic plates very coarsely beset with minute hairs; abdominal tergites smooth.

Head round, Y-suture distinct, whitish; fontanelle round, whitish, situated at the center of the suture; eye round, with no pigment, slightly prominent; ocellus round, whitish, separated from eye by a distance greater than its diameter; postclypeus trapezoidal, more than twice as broad as long; anteclypeus slightly swollen; labrum tongue-shaped, entirely overlapping

ausser Eisen und Stein." Such being the case, not only is the extermination of these insects almost impossible, but also preventive measures against their damage are difficult to apply.

Fortunately, Japan is located in a temperate region; and, therefore, her people have not been obliged to pay attention to these formidable pests. However, one species, *Leucotermes speratus* Kolbe, which very often causes somewhat serious damage to wooden structures, has been recorded in Japan since 1724. About twenty years ago, Japan occupied Formosa, which lies in a semitropical region; that is, in the western Pacific Ocean, between the southern and eastern China Seas. In this possession the people have been compelled to fight against the common pest of the Tropics, and the investigation of the biology of termites has become one of the most important problems of the architect and the entomologist.

In Formosa and in Japan there are fourteen species of termites, four of which, namely *Coptotermes formosanus*, *Leucotermes speratus*, *Leucotermes flaviceps*, and *Odontotermes formosanus*, are known as pests of wooden structures. *Coptotermes formosanus*, which is distributed in Formosa, Riu Kiu Islands, and in the southern parts of Japan proper, is especially formidable to buildings. It is certain that the other three attack woodwork, and wooden structures as well, but their ravages are negligible in comparison with those of *Coptotermes formosanus*.

During the last ten years, I have been investigating the Japanese termites, especially the habits of *Coptotermes formosanus*. I approached the problem of the method for prevention with the following ideas as a working basis:

1. Some changes are necessary with regard to the construction of buildings in the Tropics in order to prevent damage by termites.
2. The value of termite-proof building construction is not absolute, unless all sorts of nonresistant timbers are eliminated from the building materials.
3. If it shall be proved that the elimination of nonresistant timbers is practically impossible, it becomes necessary to treat them chemically or physically in order to confer a special resistant property.
4. It is necessary to prove whether or not there are naturally resistant timbers in the Tropics.
5. If there are naturally resistant timbers, an investigation with the object of discovering the cause of resistance becomes important.
6. If the causes are definitely known, methods of artificially treating nonresistant timbers will be more easily discovered.

By the kind and valuable assistance of Mr. Kinzo Kafuku, former expert chemist of the Government Institute of Science,

Formosa; Mr. Tetsukichi Katayama, chief of the chemical department of the same institute; and Mr. Saichi Tasaki, my assistant, I have carried on my investigations and very fortunately have gained some satisfactory results, which are recorded in the following pages. Here I wish to express my sincere thanks for the courtesy shown by those gentlemen and to Dr. Tomoe Takaki, former director of the above-mentioned institute, through whose most courteous assistance I have been able to continue my work for so many years.

DESCRIPTIONS OF THE FORMOSAN TERMITES INJURIOUS TO WOODEN STRUCTURES

Family MESOTERMITIDÆ Holmgren

Subfamily COPTOTERMITINÆ Holmgren

Genus **COPTOTERMES** Wasmann

Coptotermes formosanus Shiraki. Plate I, figs. 1 to 3.

Coptotermes formosanus SHIRAKI, Trans. Ent. Soc. Jap. 2 (1909) 239; OSHIMA, Rep. Term. 1 (1909) 33, pl. 1, figs. 1–3; pl. 2, figs. 11, 12; Rep. Term. 3 (1912) 75, pl. 1, figs. 8, 28; pl. 2, figs. 3, 21; Philip. Journ. Sci. § D 8 (1913) 276; Rep. Term. 4 (1914) 2; HOLMGREN, Termitenstudien 4 (1913) 76, pl. 2, fig. 10; HOZAWA, Journ. Coll. Sci. Tokyo 35 (1915) 92, pl. 3, figs. 18–20, text figs. 22–25.

Coptotermes gestroi OSHIMA, Zool. Mag. Tokyo 22 (1910) 376; Rep. Term. 2 (1911) 5; NAWA, Insect World 14 (1910) 597.

Coptotermes formosae HOLMGREN, Termitenleben auf Ceylon (1911) 192; Termitenstudien 2 (1911) 74; Annot. Zool. Jap. 8 (1912) 121; YANO, Rep. Jap. For. Exp. Station 9 (1911) 62, pl. 4, figs. 12–20.

Imago.—Head brown; anteclypeus whitish; postclypeus, antennæ, labrum, and labial palpi brownish yellow; pronotum yellowish brown, with Y-shaped marking; mesonotum, metanotum, and abdomen pale brown; legs yellow, tibia and tarsus darker; head, thoracic plates, and abdominal tergites densely pilose; wing stumps beset with hairs.

Head round, fontanelle distinct; antennæ 21-jointed, second joint cylindrical, nearly as long as third and fourth taken together; third joint short, ring-shaped; eye round, markedly prominent; ocellus oval, separated from eye by a distance less than its shorter diameter; anteclypeus trapezoidal, narrower than postclypeus, the latter short and slightly swollen; pronotum semilunar, anterior border concave, posterior border

bilobed, posterolateral corners rounded; mesonotum and metanotum narrower than pronotum, their posterior borders slightly concave; wing stumps subequal in size, anterior ones overlapping base of posterior; wings hyaline, costal margin yellowish, veins yellowish at base; wing membrane densely beset with minute hairs, radius nerve of anterior wing parallel to costal margin; median nerve faint, nearer to cubitus than to radius, with no branch; cubitus below middle of wing, not reaching tip, with about seven branches, of which the proximal four are stronger; median nerve of posterior wing starts from proximal portion of radius.

Measurements of the imago.

	mm.
Length of body with wings	14.00
Length of body without wings	6.00
Length of head	1.40
Width of head	1.31
Width of pronotum	1.31
Length of pronotum	0.87
Length of anterior wing	11.00

Queen.—Head and thorax similar to those of imago; mesonotum and metanotum with a pair of triangular wing stumps; abdomen much enlarged; abdominal tergites pale reddish brown, separated from each other by a distance about four times as great as its length; abdominal integument milk white.

Measurements of the queen.

	mm.
Length of body	21.00
Length of abdomen	19.00
Width of abdomen	5.50

King.—All the characters agree very well with those of the imago; abdomen not enlarged; thorax provided with two pairs of triangular wing stumps.

Substitute queen.—Head yellow; postclypeus somewhat paler; anteclypeus whitish; mandibles pale yellow, with brown tips; antennæ and legs pale yellow; thoracic plates yellow; abdomen milk white, with pale yellow abdominal tergites; head and thoracic plates very coarsely beset with minute hairs; abdominal tergites smooth.

Head round, Y-suture distinct, whitish; fontanelle round, whitish, situated at the center of the suture; eye round, with no pigment, slightly prominent; ocellus round, whitish, separated from eye by a distance greater than its diameter; postclypeus trapezoidal, more than twice as broad as long; anteclypeus slightly swollen; labrum tongue-shaped, entirely overlapping

mandibles; antennæ 17-jointed, second to fourth joints equal in length; pronotum semilunar, anterior border bilobed, posterior border clearly indented at middle, anterolateral corners rounded; mesonotum and metanotum much broader than pronotum, their posterior borders nearly straight, their posterolateral corners strongly projected posteriorly, forming rudimental wing pads; abdomen more or less enlarged, chitinous plates crescent-shaped.

Measurements of the substitute queen.

	mm.
Length of body	12.00
Length of abdomen	9.00
Width of abdomen	3.50
Length of head	1.25
Width of head	1.34
Width of pronotum	1.25
Length of pronotum	0.78

Substitute king.—Unknown.

Soldier.—Head yellow; mandibles dark brown; labrum brownish yellow; antennæ somewhat paler; pronotum pale yellow; abdomen and legs pale straw color; head coarsely pilose; thoracic plates hairy; abdominal tergites densely covered with short spiny hairs.

Head suborbicular, posterior border rounded, sides arcuate, strongly converging anteriorly; fontanelle distinct, opening directed forward, situated just behind the base of postclypeus; antennæ 15-jointed, second joint quadrate, longer than third, the latter narrowest and shorter than fourth; mandibles saber-shaped, slender, with incurved, piercing tip, cutting edge toothless, labrum lancet-shaped, tip hyaline, reaching middle of mandible; anterior border of anteclypeus slightly convex; postclypeus very short, not separated from forehead; pronotum subreniform, narrower than head, anterior and posterior borders slightly bilobed, lateral borders rounded, converging posteriorly; mesonotum oval, the former slightly narrower than pronotum, while the latter is broader.

Measurements of the soldier.

	mm.
Length of body	5.00
Length of head with mandibles	2.37
Length of head without mandibles	1.56
Width of head	1.18
Width of pronotum	0.84
Length of pronotum	0.50

Worker.—Head, thorax, and abdomen milk white, densely covered with short spiny hairs.

Head spherical; antennæ 15- or 16-jointed, second joint longer than third, fourth joint ring-shaped; clypeus trapezoidal, anterior border straight, boundary between anteclypeus and postclypeus indistinct; pronotum much narrower than head, semilunar.

Measurements of the worker.

	mm.
Length of body	4.50
Width of head	1.15
Width of pronotum	1.00

Distribution.—South China (Foochow and Amoy); Formosa; Kotosho (Botel Tobago Island); Riu Kiu Islands; Shikoku; Kiushiu; southern part of Honshu, chiefly the coasts along the Inland Sea.

Subfamily LEUCOTERMITINÆ Holmgren

Genus **LEUCOTERMES** Silvestri

Leucotermes (Reticulitermes) flaviceps Oshima.

Termes (Leucotermes) flavipes OSHIMA, Rep. Term. 1 (1909) 30, pl. 1, figs. 4-8; Zool. Mag. Tokyo 22 (1909) 345.

Leucotermes flavipes SHIRAKI, Trans. Ent. Soc. Jap. (1909) 231; OSHIMA, Rep. Term. 2 (1911) 3; NAWA, Insect World 15 (1911) 14.

Leucotermes flaviceps OSHIMA, Rep. Term. 3 (1912) 74, pl. 1, fig. 10; pl. 2, figs. 15-17; Philip. Journ. Sci. § D 8 (1913) 277.

Leucotermes (Reticulitermes) flaviceps OSHIMA, Rep. Term. 4 (1914) 2.

Imago.—Head chestnut brown, antennæ and abdomen somewhat darker; pronotum yellow; mesonotum and metanotum dark brown; femur dark; tibia and tarsus yellow; head, thorax, and abdomen densely covered with hairs.

Head quadrate, posterior border rounded; clypeus yellow, nearly twice as broad as long, slightly swollen, boundary between anteclypeus and postclypeus indistinct; labrum tongue-shaped, as long as broad; eyes rather small; ocellus separated from eye by a distance equal to its diameter; antennæ very long, nearly twice as long as length of head, 17-jointed, second joint as long as fourth, third joint smallest, shorter than second; pronotum narrower than head, semilunar, anterior border nearly straight, posterior border rounded, weakly incurved at middle; posterior border of mesonotum and metanotum rounded; wing stumps subequal, the anterior scarcely covering base of posterior; wings fuscous, with brownish costal margin; radius nerve of anterior wings near and parallel to costal not branched; median nerve midway between radius and cubitus, connected with the former

by many short branches, cubitus with about ten branches, not reaching tip of wing, its tip anastomosing and connecting with median nerve.

Measurements of the imago.

	mm.
Length of body with wings	9.00
Length of body without wings	4.50
Length of head	1.03
Width of head	1.00
Width of pronotum	0.90
Length of pronotum	0.59
Length of anterior wing	8.00

Soldier.—Head yellow; mandibles reddish brown; thorax and abdomen yellowish white; antennæ and legs straw-colored; head moderately pilose, thorax densely provided with short, spiny hairs; abdominal tergites densely pilose.

Head cylindrical, posterior border rounded, anterior border nearly straight, sides straight and parallel; clypeus very short, indistinctly separated from forehead; labrum lancet-shaped, tip whitish, scarcely reaching middle of mandibles; mandible saber-shaped, tip incurved, cutting margin smooth; antennæ 14- to 16-jointed; third joint smallest, nearly half as long as second; fourth joint slightly shorter than second; fontanelle indistinct; pronotum heart-shaped, anterior border bilobed, posterior border nearly straight, sides converging posteriorly, mesonotum and metanotum narrower than pronotum.

Measurements of the soldier.

	mm.
Length of head	5.00
Length of head with mandibles	2.50
Length of head without mandibles	1.75
Width of head	1.03
Width of pronotum	0.78
Length of pronotum	0.47

Worker.—Head yellowish white; thorax, abdomen, antennæ, and legs whitish; head, thorax, and abdominal tergites densely pilose.

Head round, slightly widening anteriorly; length of postclypeus less than half its width; antennæ 14-jointed, second joint nearly as long as third, fourth joint as long as third; pronotum narrower than head, anterior border bilobed, slightly raised, posterior border nearly straight, sides converging posteriorly; mesonotum nearly as broad as pronotum; metanotum much broader than mesonotum.

Measurements of the worker.

	mm.
Length of head	4.00
Width of head	1.03
Width of pronotum	0.69

Distribution.—Formosa (Taihoku, Horisha, and Koshun); Kotosho (Botel Tobago Island).

Remarks.—The present species is very closely related to *Leucotermes speratus*, from Japan proper. It is very hard to draw a fast line between the imagoes of the two species; however, the soldiers of the two species distinctly differ as follows:

a^1. Head narrow and long, 1.75 to 1.81 millimeters long, 1.03 to 1.09 millimeters broad; lateral borders of head straight and parallel; posterior border of pronotum nearly straight .... *L. flaviceps.*

a^2. Head rather broad and short, 1.56 to 1.71 millimeters long, 1.06 to 1.09 millimeters broad; lateral borders of head convex, slightly converging anteriorly; posterior border of pronotum clearly indented at middle .... *L. speratus.*

In addition, the swarming seasons of the two species are quite different. The winged forms of *L. flaviceps* swarm in the beginning of January, while those of *L. speratus* swarm in April or May.

Family METATERMITIDÆ Holmgren

Genus ODONTOTERMES Holmgren

Odontotermes (Cyclotermes) formosanus (Shiraki). Plate I, figs. 4 to 6.

Termes formosana SHIRAKI, Trans. Ent. Soc. Jap. 2 (1909) 234; OSHIMA, Rep. Term. 3 (1912) 81, pl. 1, figs. 7, 26, 27; pl. 2, figs. 11, 18.

Termes vulgaris SHIRAKI, Trans. Ent. Soc. Jap. 2 (1909) 233; OSHIMA, Rep. Term. 1 (1909) 37, pl., figs. 9, 10; Zool. Mag. Tokyo 22 (1910) 379; Rep. Term. 2 (1911) 7; MATSUMURA, Schädl. u. Nützl. Insekt. v. Zuckerrohr Formosa (1910) 2, pl. 1, figs. 2–4.

Odontotermes (Cyclotermes) formosanus HOLMGREN, Termitenstudien 3 (1910) 38; Termitenstudien 4 (1913) 116, pl. 4, fig. 11; pl. 5, fig. 11; HOZAWA, Journ. Coll. Sci. Tokyo 35 (1915) 105, pl. 3, figs. 21–23, text figs. 26–28.

Odontotermes formosanus HOLMGREN, Annot. Zool. Jap. 8 (1912) 127.

Odontotermes (Cyclotermes) formosana OSHIMA, Philip. Journ. Sci. § D 8 (1913) 278.

Imago.—Head, thorax, and abdomen chestnut; anteclypeus yellowish white; antennæ, labial palpi, T-shaped marking and anterolateral corners of pronotum, and legs brownish yellow;

wings fuscous, with yellowish subcostal band; head, thorax, and abdomen densely pilose.

Head round; fontanelle somewhat elevated, minute; antennæ 19-jointed, second joint twice as long as third, fourth joint as long as third; eye round and prominent; ocellus oval, separated from eye by a distance more than its longest diameter; post-clypeus swollen, width more than twice its length; pronotum narrower than head, subsemilunar, anterior border nearly straight, sides strongly converging posteriorly, posterior border rounded, slightly curved at middle; mesonotum and metanotum longer than pronotum, their posterior borders strongly indented at middle; anterior wing stumps somewhat larger than posterior, not covering the latter; radius nerve of anterior wing runs near and parallel to costal, with no branch; median nerve starts from proximal part of cubitus, giving off four bifurcating branches at the apical area, cubitus with about ten branches, not reaching tip of wing; median nerve of posterior wing starts from basal part of radius.

Measurements of the imago.

	mm.
Length of body with wings	27.00
Length of body without wings	9.00
Length of head	2.20
Width of head	2.00
Width of pronotum	24.00
Length of pronotum	1.20
Length of anterior wing	24.00

Soldier.—Head reddish yellow; mandibles reddish brown; labial palpi, antennæ, and legs yellow; abdomen pale yellowish white; head, thoracic plates, and abdominal tergites sparingly pilose, long hairs mingling with subequal minute hairs.

Head ovoid, longer than broad, sides slightly converging anteriorly; antennæ 16-jointed, third joint smallest, second joint about twice as long as third, fourth joint shorter than third; mandibles saber-shaped, with incurved and upcurved tip, each mandible provided with one tooth, of which the left one is stronger and distinct; labrum lancet-shaped, scarcely reaching middle of mandible, with acutely rounded tip; clypeus very short, not separated from forehead; pronotum slightly broader than long, anterior border elevated and distinctly bilobed, posterior border rounded, concave at middle; mesonotum oval, nearly as broad as pronotum, posterior border curved at middle; metanotum much broader than pronotum, posterior border rounded.

Measurements of the soldier.

	mm.
Length of body	4.50
Length of head with mandibles	2.12
Length of head without mandibles	1.40
Width of head	1.12
Width of pronotum	0.74
Length of pronotum	0.47

Worker.—Head yellow; clypeus somewhat paler; antennæ and legs straw-colored, thorax and abdomen whitish; head moderately pilose; thorax and abdominal tergites densely provided with minute hairs.

Head spherical; antennæ 17-jointed, third joint smallest, second joint elongate, more than twice as long as third, fourth joint slightly longer than third; postclypeus swollen, more than twice as broad as long, anterior border concave; anteclypeus whitish, anterior border convex; pronotum saddle-shaped, much narrower than head, anterior border strongly elevated, indented at middle, posterior border rounded, curved at middle.

Measurements of the worker.

	mm.
Length of body	3.50
Width of head	1.31
Width of pronotum	0.62

Distribution.—*Odontotermes formosanus* is one of the commonest species in Formosa. It has been recorded from Ishigakijima and South China (Amoy and Foochow).

Remarks.—This species attacks living plants. It is a serious pest to sugar cane and young camphor trees.

CERTAIN HABITS OF COPTOTERMES FORMOSANUS SHIRAKI

DIFFERENT CASTES IN THE COLONY

Generally the members of a termite colony differ greatly at different times of the year. Eggs and newly hatched larvæ of *Coptotermes formosanus* are most numerous in the summer; winged forms and nymphs are not present after the swarming season (from the end of May to the beginning of June); nymphs increase in number in the spring, becoming most abundant in April; at the end of May the nymph changes to an imago and usually swarms during the first ten days of June. A complete colony contains the following castes:

1. Newly hatched larvæ. The heads of all are alike in dimensions and are provided with 10-jointed antennæ.
2. Larvæ of soldier, derived from 1. Distinctly differs from the other castes in having somewhat elongate, toothless mandibles and suborbicular head.

3. Larvæ of worker, derived from 1. Large-headed and provided with clearly denticulated mandibles, the tip and the inner margin of which are more or less brown.
4. Larvæ of royal form, derived from 1. Small-headed; other external characters are similar to those of worker larvæ.
5. Nymph of royal form. The members of this caste are provided with two pairs of wing pads and one pair of nonpigmented eyes and ocelli; body milk white.
6. Winged forms with pigmented eyes. Body reddish brown. At the beginning of May vast numbers of this caste are found in the nests; they emerge from the old nest early in June.
7. A single queen, derived from a female of the winged form. Abdomen greatly enlarged, with two pairs of triangular wing stumps on the thorax.
8. A single king, derived from a male of the winged form. Abdomen normal, with two pairs of triangular wing stumps on the thorax.
9. Substitute royal forms. It is certain that there are several kings and queens belonging to this class; however, the substitute king is not known. The substitute queen which was collected in Kiushiu by Mr. Tatsuo Yoneyama, engineer of the Imperial Railway, is 12 millimeters long; head yellow, abdomen milk white, thorax with no wing stumps. This caste is very rare in the colony of *Coptotermes formosanus*. According to Yoneyama's information, the nest which contained this queen was orphaned and some fifteen of the same form were captured at the same time.

The following are descriptions of young forms, given somewhat fully:

Newly hatched undifferentiated larvæ.—Head, thorax, and abdomen milk white and densely provided with minute hairs.

Head squarish, sides strongly converging anteriorly, posterior border nearly straight, posterolateral corners rounded; antennæ 10-jointed, joints enlarging apically, first joint quadrilateral, second joint slightly shorter than first, broader anteriorly, third joint semidivided, slightly shorter and narrower than second, fourth to sixth joints ring-shaped, seventh to ninth joints spherical, apical joint elongate, oval, slightly narrowed anteriorly; anteclypeus short, its anterior border rounded; postclypeus not separated from forehead; labrum tongue-shaped, longer than broad, anterior border rounded; mandibles triangular, tip obtusely rounded, cutting margin of both sides with traces of minute teeth; pronotum narrower than head, crescent-shaped, posterior border rounded; mesonotum and metanotum broader than pronotum.

Measurements.

	mm.
Length of body	1.50
Length of head	0.27
Width of head	0.52
Width of pronotum	0.26
Length of pronotum	0.10

Larva of soldier, with 12-jointed antennæ.—All parts of body milk white; tips of mandibles pale brown; head coarsely pilose; thoracic plates hairy; abdominal tergites densely covered with short hairs.

Head broadly oval, slightly longer than broad, broader anteriorly; fontanelle indistinct; antennæ 12-jointed, second joint nearly as long as third, third joint narrowest, fourth joint shorter than second, fifth to ninth joints spherical, apical joint elongate, narrower anteriorly; clypeus twice as broad as long, anterior border rounded, boundary between anteclypeus and postclypeus indistinct; labrum lancet-shaped, mandibles rather short and broad, with pointed and incurved tip; pronotum narrower than head, oval, anterior and posterior borders rounded; mesonotum and metanotum round, the former narrower than the latter and broader than pronotum.

Measurements.

	mm.
Length of body	4.00
Length of head with mandibles	1.50
Length of head without mandibles	0.93
Width of head	0.90
Width of pronotum	0.53
Length of pronotum	0.31

Larva of royal form, with 12-jointed antennæ.—Head, thorax, and abdomen whitish and sparingly provided with minute hairs.

Head round, nearly as long as broad, anterior corners of transversal band yellowish brown; postclypeus slightly swollen, longitudinally depressed along median line; anteclypeus as long as postclypeus, anterior border rounded; labrum tongue-shaped, overlapping the mandibles; mandible triangular, cutting edge dark brown; antennæ 12-jointed, second joint as long as fourth, third joint smallest, nearly half as long as second; pronotum ovoid, anterior border convex, slightly emarginate at middle, posterior border rounded; mesonotum and metanotum broader than pronotum, mesonotum narrower than metanotum.

Measurements.

	mm.
Length of body	3.50
Length of head	0.84
Width of head	0.87
Width of pronotum	0.50
Length of pronotum	0.21

Remarks.—In the present phase the external characters of the larva of the worker are similar to those of the larva of the royal form, except the size of the head. The former is provided

with a much larger head, measuring 0.91 to 0.94 millimeter long and 0.88 to 0.91 millimeter broad; while the latter has a smaller head, measuring 0.84 to 0.91 millimeter long and 0.84 millimeter broad. This distinction between the two forms is observable in the earlier stage when the larvæ are provided with 11-jointed antennæ.

Nymph of royal form.—Head, thorax, and abdomen milk white; eyes nonpigmented; head and pronotum sparingly pilose; wing pads with a few short hairs; abdominal tergites densely covered with minute hairs.

Head round, slightly broader than long; fontanelle spotted, round and white, situated at center of head; eyes round and prominent; ocellus separated from eye by a distance equal to its diameter; postclypeus short, anterior border nearly straight, shorter than posterior; anteclypeus as long as postclypeus, with rounded anterior border; labrum tongue-shaped, sides slightly converging posteriorly, tip and cutting margin of mandibles dark brown; antennæ 19-jointed, second joint longer than third, fourth joint nearly as long as second, semidivided; pronotum semicircular, anterior border concave, posterior border indented at middle, anterolateral corners rounded; lateral parts of mesonotum and metanotum much produced posteriorly, forming primitive wing cases, which are provided with rudimental veins.

Measurements.

	mm.
Length of body	8.50
Length of head	1.15
Width of head	1.31
Width of pronotum	1.40
Length of pronotum	0.93

THE FOUNDATION OF A NEW COLONY

In Formosa the swarming of *Coptotermes formosanus* takes place at the end of May or early in June, while in Japan proper the winged individuals swarm a little later; that is, at the end of June.

TABLE I.—*Records of the swarming season of Coptotermes formosanus.*

Year.	Formosa.	Japan proper.
1912	No record	June 12 to 19; at Marugame.
1913	June 1; at Taihoku	June 26; at Mitajiri.
1914	June 3; at Taihoku	June 25; at Gifu.
1915	June 1; at Taihoku	No record.
1916	June 4; at Taihoku	Do.
1917	June 8; at Taihoku	Do.

After the adults have rapidly emerged from the parent nest in a vast swarm and have flown a short distance in an irregular, wobbly manner, they fall to the ground. As soon as they reach the ground, they cast the wings. Then the male is attracted to the female and follows her tirelessly and closely, performing the so-called "Termiten Liebes-Spaziergang." In this manner the imagoes separate into pairs and enter hiding places in order to establish new colonies, usually under pieces of decaying wood, in holes and crevices in wood, or directly in the earth.

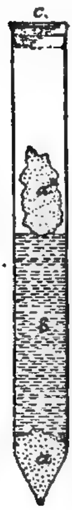

FIG. 1.

In order to observe the starting of a new colony, many new couples were captured in glass tubes, arranged as shown in fig. 1.

The bottom of a test tube, 2 by 16 centimeters, is bored with a capillary pore, and a piece of absorbent cotton, *a*, is inserted. Then a proper quantity of crushed clay, *b*, is placed in the tube to serve as the abode of the future colony; upon this layer pieces of soft wood or cotton, *a*, are laid for food. A male and a female that have recently flown from the nest are now placed in the tube, which is tightly corked and put in a dark place.

In order to keep captive termites in a healthy condition, it is absolutely necessary to give them proper humidity. This is done by placing the end of the tube in water, thus allowing the absorbent cotton to draw a sufficient amount of water through the pore. As a result of these investigations, the following facts were determined:

1. During the first stage of colonization both the male and the female are active. They forage for themselves and are equally important in establishing the new colony and in rearing the first brood of young.
2. Egg laying in a newly established colony begins from five to thirteen days after the swarming.

TABLE II.—*Time between swarming and egg laying.*

RECORDS FOR 1915.

Days after swarming.	Cases.
5	3
6	8
7	10
8	5
9	6
10	5
11	3
12	2
13	3

TABLE II.—*Time between swarming and egg laying*—Continued.

RECORDS FOR 1916.

Days after swarming.	Cases.
5	9
6	3
7	7
8	8
9	9
10	3
12	2

3. The rate of egg laying is not rapid in the first batch, one to four eggs being laid on one day.
4. Eggs hatch out in from twenty-four to thirty-two days after they are laid.
5. After five months of captivity, the nests in two of the tubes were opened. In these there were no unhatched eggs; the king and the queen, which still retained the normal form of the imago, ran actively, in company with rather small individuals of the worker type and soldiers. The number of individuals in each nest agreed well; one contained twenty-two individuals of the worker type and two soldiers, the other, twenty individuals of the worker type and three soldiers. These facts clearly show that about twenty-five eggs compose the first batch in a newly established colony, and that no more eggs are laid until the eggs of the first brood are all hatched.
6. In the first brood the soldiers are few in comparison with individuals of the worker type, about 10 per cent of the number of the latter being soldiers.
7. Soldiers hatch from the eggs that are laid by true royal females.[3]

SITUATION OF THE NEST

Coptotermes formosanus does not construct a large mound as do some species in the Tropics. Usually it makes its nest in the ground at a depth of from 6 to 10 feet (1.82 to 3.04 meters). Very often the nest is made at the junction of rafters of buildings or in the inner part of infested timbers, in wooden boxes or cabinets, or in the interspaces in walls. Generally the nest is round and honeycombed, and in the center there is a small, slitlike royal chamber (Plate II; Plate III, fig. 2).

The nest consists of a mixture of abdominal excreta and clay or sand, pasted together with a special secretion of the salivary glands. Sometimes it is rigid and compact and seems like a piece of rock. However, it is inflammable and burns rapidly, leaving a small amount of ash.

[3] As it is almost impossible from external characters to draw a fast line between larvæ of royal forms and of workers, nothing at present can be said with regard to the origin of these two forms.

TABLE III.—*The rate of egg laying, Coptotermes formosanus.*

Date.	Eggs.		Larvæ.	
	Total.	Increase.	Total.	Increase.
May 20[a]				
May 26	3	3		
May 27	4	1		
May 28	6	2		
May 29	7	1		
May 30	8	1		
May 31	10	2		
June 1	10			
June 2	10			
June 3	10			
June 4	10			
June 5	12	2		
June 6	16	4		
June 7	16			
June 8	18	2		
June 9	18			
June 10	18			
June 11	18			
June 12	22	4		
June 13	22			
June 14	22			
June 15	22			
June 16	22			
June 25	22			
June 26	19		3	3
June 27	17		5	2
June 28	16		6	1
June 29	13		9	3
June 30	13		9	
July 1	13		9	
July 2	13		9	
July 3	12		10	1
July 4	12		10	
July 5	14	4	12	2
July 6	12	1	15	3
July 7	12	4	19	4
July 8	13	1	19	
July 9	13		19	
July 10	13		19	
July 11	13		19	
July 12	12		20	1
July 13	12		20	
July 14	12		20	
July 15	11		21	1

[a] Date of capture.

DAMAGE TO BUILDINGS AND OTHER MATERIALS

Coptotermes formosanus is essentially a wood destroyer and attacks very seriously all sorts of woodwork and wooden structures. Because of its habit of attacking Japanese pine, which is

an important building material, it is classed as a most formidable pest throughout Formosa. Moreover, as the method of attack of this insect is insidious, usually leaving the outer layer of wood intact as a protective covering from sunlight and its natural enemies, so that the damage is always hidden until beyond repair, it is a most dangerous enemy to buildings (Plate IV).

TABLE IV.—*The rate of egg laying, Coptotermes formosanus.*

Date.	Eggs.		Larvæ.	
	Total.	Increase.	Total.	Increase.
May 20[a]				
May 25	2	2		
May 26	5	3		
May 27	5			
May 28	5			
May 29	6	1		
May 30	8	2		
May 31	9	1		
June 1	11	2		
June 2	13	2		
June 3	14	1		
June 5	14			
June 6	15	1		
June 7	15			
June 8	16	1		
June 11	16			
June 12	17	1		
June 14	17			
June 15	18	1		
June 16	19	1		
June 19	20	1		
June 21	20			
June 22	20			
June 23	20			
June 26	20			
June 27	17		3	3
June 28	16		4	1
June 29	15		5	1
June 30	14		6	1
July 3	10		10	4
July 5	6		14	4
July 7	6		14	
July 8	4		16	2
July 10	4		16	
July 11	3		17	1
July 12	3		17	
July 13	0		20	3

[a] Date of capture.

TABLE V.—*Incubation period of eggs of Coptotermes formosanus.*

Days.	Cases.
RECORDS FOR 1915.	
25	1
26	1
27	2
30	1
RECORDS FOR 1916.	
24	1
26	4
27	7
28	5
29	3
30	5
31	5
32	4

In infesting buildings it generally gains entrance from outdoor colonies. By means of subterranean tunnels of considerable length, which originate from a nest in the ground, it reaches the foundation of a building. At first it attacks foundation timbers, flooring, or supports of porches or steps that are in contact with the ground, and gradually extends its tunnels and excavation into the first, the second, or even the third floor and into the roof, passing through the walls or the interior of timbers (Plate VI, fig. 1).

In cases where the foundation is of stone, concrete, or other impermeable material, it constructs a covered tunnel of a mixture of earth and saliva over the surface and reaches the woodwork. Generally a cross section of this artificial tunnel is semicircular, the diameter being from 5 to 10 millimeters (Plate VII, fig. 1).

Damage to buildings.—Ordinary Japanese houses are chiefly constructed of wood and clay, the foundation timbers being laid in contact with the ground. Thus the construction itself is not fitted to prevent the attack of termites. Moreover, Japanese pine and cryptomeria, which are most liable to be attacked by *Coptotermes formosanus*, are the principal building materials. Such being the case, the Japanese people suffer a great deal from the damage when they erect buildings of their own style in Formosa.

As the work of *Coptotermes formosanus* is hidden, it is difficult to detect the presence of the insects or the damage that they are doing. After they have caused the fall of a building, the beams, the rafters, and other important parts of the woodwork are often found to be mere shells, the interior being entirely honeycombed (Plates V and VI).

Damage to brick walls.—There are several records in Formosa of modern brick buildings having been infested by *Coptotermes formosanus.* It is absolutely impossible for it to attack brick itself; but, according to my actual observation, the mortar which is used as a cementing material for bricks is subject to attack.

In building a thick brick wall the following method is adopted: The face bricks are laid upon a bed of mortar; the mortar, in a semifluid condition, is then poured into the space between the face bricks; the bricks are then pushed rapidly, horizontally for a short distance, into their position; a certain amount of the mortar is thus displaced; this rises in the side joints and completely fills all the interstices; should the mortar not rise to the top of the joints, the vacant spaces are filled up, when the next course is larried.

All the interstices between the bricks would be completely filled, if the bedding could be carried on theoretically; but this is practically impossible, so that there are almost sure to be voids in brick walls. Under such conditions, termites prefer to pass through brick walls, if they have a chance to permeate them, rather than to excavate ordinary walls; because the voids are always in a favorable condition for their life, being protected from the sunlight and containing a proper amount of moisture.

There are two kinds of mortar used for constructional work; namely, cement mortar and lime mortar. The former is composed of sand and Portland cement (the ratio of Portland cement to sand is from one to two to one to four), while the latter is composed of moderately hydraulic lime and sand (the ratio of lime to sand is usually one to two).

In Formosa until a comparatively recent date lime mortar was exclusively used for the bedding of bricks. It has been found, however, that *Coptotermes formosanus* easily penetrates brick buildings and causes serious damage (Plate VII). Since the Government has required the use of cement mortar instead of lime mortar there has been no record of damage to brick walls. Therefore, it seems reasonable to conclude that there exists some special relationship between lime and the destructive power of *Coptotermes formosanus.*

The soldier of *Coptotermes formosanus* is provided with a special gland on the forehead, which secretes a milky, acidulous fluid; its excreta and saliva are also acidulous, while those of the worker are alkaline. In the passages perforating the lime

mortar of brick walls vast numbers of soldiers are found. Such being the case, it is said that the soldier of *Coptotermes formosanus* attacks lime mortar by dissolving the lime with the acidulous secretions.

Damage to railway sleepers.—*Coptotermes formosanus* attacks railway sleepers as well as buildings. According to a statement of the Bureau of the Formosan Government Railway, the life of an untreated, chestnut sleeper is only two years in Formosa, while in Japan proper it is from eight to ten years.

In the southern part of Formosa another species of termite, *Odontotermes formosanus*, also attacks the sleepers, as shown in Plate VIII, fig. 3. The damage it causes is rather more serious than that caused by *Coptotermes formosanus*. Therefore, in the case of sleepers, it is important to prevent the damage caused by these two species. Usually the length of the spike which is used to fix the rail to a sleeper is a little greater than the depth of the latter, so that its tip always penetrates beyond the bottom of the sleeper, causing some damage to that surface (Plate VIII, fig. 1). This point is most liable to be attacked. As the pests excavate the wooden tissue surrounding the spike (Plate VIII, fig. 2), the latter becomes ineffective. Suppose such damage occurs successively in several sleepers; the results are quite obvious—the rails spread and cause great danger to passing trains.

Damage to ships.—One can hardly believe that steamships and launches in the water have been attacked by *Coptotermes formosanus;* but it is an undeniable fact. There are many records of such cases in the harbor of Keelung, Formosa. It happens in this way. In the swarming season, many thousands of winged males and females start from the nests in the vicinity of the shore. Some of them have a chance to fly into the ships moored in the harbor and there start new colonies. The interior of the ship is dark enough to favor the establishment of a nest. Usually the bottom of the ship is constructed of Japanese pine, which is most durable in water; all the timbers contain a favorable amount of water. Thus, all conditions being exceedingly favorable to *Coptotermes formosanus*, the ravages are extended step by step, until the vessel becomes unseaworthy, because of the unexpected destruction of important parts of the woodwork. In such a case extermination of the pests is very difficult. When the Government trawler *Ryokai-maru* was found to be infested, it was purposely sunk in the sea in order to destroy the insects.

Besides the above-mentioned damage, that done to bridges, telegraph poles, books, paper, wood pulp, cotton, and clothing is sometimes very serious.

PRINCIPAL FOOD OF COPTOTERMES FORMOSANUS

The stem of an exogenous perennial is a complex of structural elements of varied form and function. Of these we may distinguish three main groups: *a*, vessels; *b*, wood cells proper; *c*, medullary tissue. The growing cell of plant tissue consists of cell wall and protoplasm, the living functions depending upon the activity of the latter. However, the above-named three main structural elements of the wood do not contain nitrogenous substance—that is, protoplasm—but mainly consist of the special constituent of the cell wall known as cellulose.

There are, as might be expected, a great many varieties of cellulose, and the term must be taken as denoting a chemical group. Cellulose, taken as a group, presents the following characteristic: A colorless substance, insoluble in all simple solvents; generally but variously resistant to oxidation and hydrolysis; nonnitrogenous, having the empirical constitution characteristic of the carbohydrates. The composition of pure cellulose is represented by the percentage numbers C 44.2, H 6.3, O 49.5, corresponding to the empirical formula $(C_6H_{10}O_5)_x$. It is flexible, slightly elastic, permeable, but only slightly absorbent, and does not readily undergo fermentation. When treated with acid it passes into a starchlike condition, as is evidenced by its turning blue with iodine; and under certain conditions in the living plant it would seem capable of being formed from sugar or of passing into it.

It must be noted, however, that the typical cellulose is not separated from the plant in a pure state, but in admixture or in intimate chemical union with other compounds or groups of compounds. The latter are distinguished by greater reactivity; for example, they readily yield to alkaline hydrolysis, to oxidation, or to the action of the halogens. In the latter is included the very important group of lignified cellulose, or lignocellulose, distinguished by the presence of ketohexene groups in union with the cellulose, and therefore combining directly with the halogens.

Generally, walls of cellulose, fibers, and vessels in the wood acquire mechanical strength or resistance by undergoing a change known as lignification. This consists in their impregnation with a substance known as lignin, forming a compound

cellulose, namely, lignocellulose. Lignin, like cellulose, consists of three elements—carbon, hydrogen, and oxygen—but in different proportions, its percentage composition being C 49, H 6, O 44. Its chemical constitution is as yet unknown. It is harder and more elastic than cellulose, readily permeable by water, but not absorbent. It is more soluble in acids than is cellulose and is recognized by turning deep magenta when treated with phloroglucinol in hydrochloric acid.

As shown in the preceding pages, *Coptotermes formosanus* seriously injures all sorts of woodwork and wood products. However, why it attacks such materials or, in other words, what was the principal food of *Coptotermes formosanus* contained in wood was quite unknown. In order to settle this question the following experiments were made:

Experiment 1.—A living worker or soldier of *Coptotermes formosanus* was placed on a microscope slide, and the tip of its abdomen was pressed, the excrement being thus discharged. This was treated with phloroglucinol in hydrochloric acid under a cover glass. The color changed to deep magenta, showing the characteristic reaction of lignin.

Experiment 2.—A piece of the nest was treated with the same reagent. It also gave a deep magenta coloration, characteristic of lignin.

Experiment 3.—A piece of camphor wood and a nest of *Coptotermes formosanus* made from camphor wood were analyzed.

TABLE VI.—*Composition of camphor wood and of a nest of Coptotermes formosanus. Analyzed by T. Katayama.*

[Numbers give percentages.]

	Water.	Ash.	Aqueous extract.	Pentosan.	Cellulose.	Noncellulose.
Camphor wood	11.51	1.29	4.53	13.92	48.35	20.40
Nest	11.39	17.86	4.83	6.02	12.73	47.17
Nest (calculated as a substance with no ash)	13.87	0.00	5.88	7.33	15.50	57.42

It is quite obvious that the amount of cellulose is the main difference between the constituents of the camphor wood and those of the nest. As there occurs no decrease of noncellulose, it is clear that cellulose has been taken as the food when the camphor wood passed through the alimentary canal; and noncellulose, that is, lignin, which is produced as a decomposed material of lignocellulose by the special function of the alimentary canal, is discharged as the building material of the nest.

Experiment 4.—In order to confirm the results obtained in experiment 3, *Coptotermes formosanus* in captivity in the special tube was fed with cotton wool, which is pure cellulose. It was observed that it lives more actively than when soft woods are given as food, perforating and eating the cotton wool.

As a result of the above experiments the following facts were found:

1. The principal food of *Coptotermes formosanus* is cellulose.
2. *Coptotermes formosanus* decomposes lignocellulose into cellulose and noncellulose, namely, lignin, and builds its nest with the latter.
3. Cellulose is the principal constituent of the cell walls of plant tissue. Therefore, almost all sorts of wood are attacked by *Coptotermes formosanus.*
4. Paper, wood pulps, books, and cotton wool are liable to be attacked, because they consist of pure cellulose.
5. According to a statement of Thomas E. Snyder, *Leucotermes flaviceps,* the commonest termite in the United States, also attacks books, wood pulp, pasteboard, and rolls of cloth very seriously. This seems to indicate that cellulose may be the principal food of the majority of termites.

TERMITE-PROOF BUILDING CONSTRUCTION

Serious damage to the Japanese buildings in Formosa is due to the Japanese timbers that are used as the principal building materials; namely, pine and cryptomeria. They are most liable to damage, because they contain a large amount of cellulose in comparison with other timbers, as shown in Table VII.

TABLE VII.—*The amount of cellulose and noncellulose contained in various timbers.*

	Cellulose.	Noncellulose.
	Per cent.	*Per cent.*
Ebony	29.19	48.08
Oak	39.47	34.30
Teak	43.12	38.16
Mahogany	49.07	27.91
Cryptomeria	50.29	25.13
Pine (heartwood)	51.39	22.69
Pine (spring wood)	53.33	21.77

When Japan occupied Formosa, Japanese architects had had no experience in regard to methods of preventing the damage caused by termites. Therefore, they erected buildings there just as in the mother country, paying no attention to the termite. This is another reason for the serious damage, for Japanese buildings are not suited to the Tropics. They rather attract the

termite, since the foundation timbers are laid in contact with the ground.

From the point of view of economy, it is impossible to eliminate such nonresistant timbers from Japanese buildings. Therefore, a discovery of a new method of building construction, by which the attack of the termite can be absolutely prevented, becomes an important problem.

As a result of bitter experience during the last twenty years, the method of constructing buildings and the treatment of nonresistant timbers have been greatly improved. As it is practically proved that the termite-proof building construction that has been recently adopted by the Government of Formosa is somewhat satisfactory, I, having been chiefly concerned with the investigation, wish to explain the method in detail.

Disinfection of the ground.—Not only is *Coptotermes formosanus* widely distributed throughout Formosa, but it occupies the whole ground densely; so that, as a first step in erecting a building, it is absolutely necessary, to destroy the pest, to keep the site free from the source of the damage. For this purpose, heavy oil of petroleum, creosote oil, or Termitol (a mixture of heavy oil of petroleum and cresol) is sprinkled over the whole surface of the site, using 1 gallon (about 4 liters) of the fluid to 6 square feet (about 0.6 square meter) of area.

These fluids are nonvolatile at ordinary temperature and insoluble in water. They are effective for a long time, as they remain in the ground unchanged.

Footings.—To keep a wooden building free from termites, care should be taken not to use timbers in contact with the ground. To do this, it is necessary to use bricks and concrete in footings, even in the case of a wooden building.

The termite-proof concrete layer.—In order to prevent the entering of the termite, it is necessary to disconnect the upper parts of buildings from the soil. After the footings have been completed, a layer of cement concrete about 6 inches (about 15 centimeters) thick is spread over the whole area of the site at ground level, the edges being extended about 3 feet (about 1 meter) beyond the external walls of the building. Along the edges small drains are made, surrounding the whole concrete layer. Then the entire surface of the layer is covered with a thin stratum of cement mortar to fill up all the pores and cracks (Plate IX, fig. 1).

To reach the building, termites must either penetrate the concrete layer or cross the drains from the outside. It is proved,

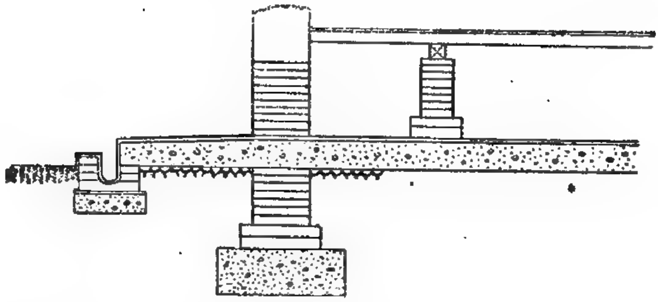

FIG. 2. Detail of termite-proof construction; a continuous layer of cement at ground level.

however, that cement concrete is quite safe against the attack of the termite, while lime concrete is not. Not only is the first method of attack almost impossible, but the second as well, for the drains are so constructed that they catch rain water from the eaves and thus prevent the intrusion of the pest. In the dry season the termite very often crosses the drains; but its covered tunnels can be found at once and it is readily driven out, because the outer parts of the concrete layer extend beyond the external wall and are used as sidewalks.

The aim of constructing a continuous layer of concrete above the ground level is to prevent absolutely the entering of the termite by means of an impermeable barrier. Great care should be taken, therefore, to keep the whole layer perfectly compact, and to avoid the occurrence of cracks and pores. To do so, the entire layer must be spread at the same time, in a continuous, even plane.

One of the practical difficulties of constructing a continuous concrete layer is that it stops construction of all other parts of the building until the concrete is entirely set. To get rid of this difficulty, the methods shown in figs. 3 and 4 are very often adopted. The concrete layer is divided into two or three

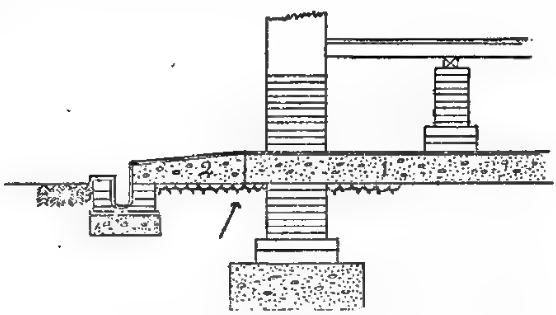

FIG. 3. Detail of termite-proof construction; a layer of cement at ground level laid in two parts.

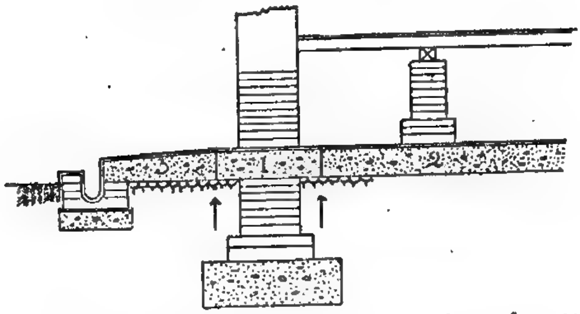

FIG. 4. Detail of termite-proof construction: a layer of cement at ground level laid in three parts.

parts, and each part is spread over the ground at a different time. After all the parts are joined together, the whole surface is covered with cement mortar. At a glance such a concrete layer seems as satisfactory as the ordinary layers. However, junctions between the sections are not tight enough to prevent the intrusion of the termites, and in many cases it was proved that the concrete layer had been penetrated by *Coptotermes formosanus* when it was ill-constructed; that is, with the layer divided into several parts.

Sometimes the architect is required to build the ground floor somewhat higher than the ground level. In such cases the concrete layer should be constructed as shown in fig. 5, and the two layers on different levels connected by another vertical

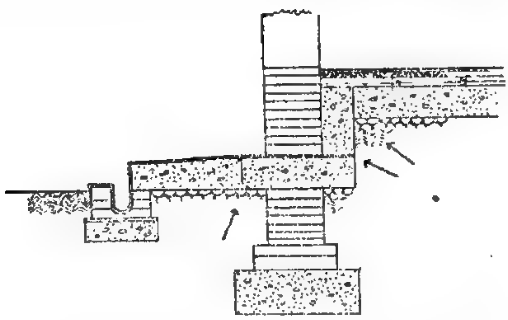

FIG. 5. Detail of termite-proof construction; the protective layer at two levels.

layer. This method is not advisable, however, because of the presence of many junctions, which are liable to be passed through by the termite. If it is necessary to raise one part of the floor, it is better to make two concrete layers separately, instead of joining the two.

First floor.—Dark places with a proper quantity of moisture are most favorable for the habitation of *Coptotermes formo-*

sanus. It is necessary, therefore, to provide ventilation holes and skylights for inclosed spaces, such as underparts of floors or inner parts of roofs.

In the case of storehouses or other special buildings the termite-proof concrete layer may be directly used as the first floor, as shown in Plate XII, fig. 1; but in ordinary houses the first floor should be raised about 3 feet (about 1 meter) above the concrete layer, by means of brick walls and brick supports. Two methods are adopted for constructing the first floor: *a*, the external parts of the building are entirely surrounded with brick walls about 3 feet (about 1 meter) high, which are provided with square ventilation holes, 2 by 1.2 feet (about 0.6 by 0.4 meter), situated 6 feet (about 2 meters) apart; the floor rests upon square brick supporters (text fig. 2; Plate XIII, figs. 1 to 5); *b*, the floor is placed upon brick arches as shown in Plate XII, fig. 2. Even in wood construction the present method is adopted, all woodwork being placed upon brick supports.

The advantages of this construction are as follows: None of the woodwork is in contact with the ground; the basement of the building is always kept dry and clean; the ample light makes inspection easy; and it is effective in keeping the building free from rats and mice, which are the propagators of the plague.

Second floor; brick building.—The second floor is constructed of reënforced concrete just like the concrete layer on the ground level, making a continuous plane. Its edges are extended to the external part of the walls, instead of being partially inserted into the brick walls as shown in Plate XIII, fig. 1. The upper and the lower surfaces of the layer are covered with cement mortar, and all the crevices, even the holes made for gas and water pipes, etc., are carefully filled. Brick walls and partitions on the second floor should be absolutely disconnected from those of the lower floor in order to confine any damage to a limited area. In addition a number of ventilation holes or windows are made through the external walls to expose to the light the inclosed space between the second floor and the ceiling of the lower story (Plate XIII, figs. 2 and 3).

Second floor; wood construction.—The distance between the beams of the second floor and the ceiling of the lower story is somewhat extended, and several ventilation holes or windows are made in the external walls to allow sufficient light to enter the interspace (Plate XIII, fig. 5).

Roofs.—Both in brick and wooden buildings the inside of the roof is usually dark and contains a lot of timber, thus render-

ing it a favorable habitat for the termite. To get rid of this danger the interspace between the tiebeams and the ceiling is somewhat extended and several windows are made in the external walls as shown in Plate XIII, figs. 4 and 5.

Brick walls.—Care should be taken to prevent the entrance of the termite into brick walls, because it is difficult to destroy the insect, which lives in the voids between the bricks. In order to prevent its intrusion, the surface of brick walls should be entirely covered with cement mortar as shown in Plate XIII, fig. 3.

Tiles.—Two kinds of tiles are used for roofing Japanese houses; namely, ordinary tile and hanging tile. In laying the former, wet clay is used for bedding; the tiles are embedded in clay one by one and fixed to each other with lime mortar. Clay is never used with the other kind, the tiles being laid on the roof directly and fixed with pieces of wire. It is desirable to use the hanging tile only, for the layer of clay is occasionally used as an abode by the termites when they reach the roof.

Timbers.—All the timbers that are used in hidden places are treated with Termol, a special chemical made in the Camphor Bureau of the Government. Both immersion and impregnation are adopted for treating timbers.

Mortar and concrete.—It is strictly forbidden to use lime mortar and lime concrete, for lime is attacked by the termite. In constructing Government buildings, cement mortar and cement concrete only are used.

DEFECTS OF THE TERMITE-PROOF BUILDING CONSTRUCTION

It has been proved that if the concrete layer be kept in a sound condition—in other words, if there are neither cracks nor joints in the layer—the above-described method of construction is entirely satisfactory in preventing the intrusion of the termite from the ground. But there are many records in Formosa of theoretically well-constructed termite-proof buildings being infested by termites, notwithstanding the existence of a perfect concrete layer.

Is there any defect in the present termite-proof building construction, or is there some way by which termites can infest buildings that is not controlled by means of the concrete layer? The answer to these questions is very simple.

As shown on a preceding page the mature males and females of *Coptotermes formosanus* leave the old nest in a swarm early in June. After separating into pairs, each couple establishes a

new colony, raising a number of workers and soldiers. It is possible, therefore, that in the case of a building infested by the winged forms, the damage may be extended year after year, in spite of the existence of the termite-proof concrete layer.

The office of the Nippon Yusen Kaisha at Keelung, Formosa, which was built in 1915 (Plate X, fig. 1), is said to be a good example of the termite-proof construction. Nevertheless, in August, 1916, that is, only one year later, damage caused by termites was found on the second floor (Plate X, fig. 2). At that time there was no damage on the first floor; there was no connection between the nests constructed on the second floor and the ground; the concrete layer on the ground level was perfect, having neither crack nor joint; many hyaline wings, which had been cast by the imagoes of *Coptotermes formosanus*, were found in the building; couples accompanied by young larvæ were found in the brick walls, especially in wood bricks. Such being the case, there could be no doubt that the building had been infested by the winged form, which entered the house in the swarming season.

The concrete layer on the ground level may be strong enough to prevent the pest that starts from the ground, but it is of no use in preventing the intrusion of the winged forms. Certainly, in Formosa, the percentage of the damage to buildings has decreased since the new method of construction was adopted; but the present building construction is not absolutely termite proof, because it does not prevent the entrance of the winged forms.

TESTS OF THE RELATIVE RESISTANCE OF NATIVE AND EXOTIC WOODS

It is evident that the changes made in several parts of buildings in Formosa are more or less effective in preventing the damage by *Coptotermes formosanus;* but, since it is almost impossible to prevent the entrance of the winged forms, an investigation to discover other methods of prevention becomes necessary.

From an economic point of view it is hard to eliminate nonresistant timbers from building materials, especially in the case of Japanese buildings. Under such conditions the treatment of timbers so as to provide immunity from the attack of the termite is considered more important than the former method; because it is certain that the preventive measures, namely, constructing the concrete layer, etc., become unnecessary if the nature of timbers can be so changed that they are absolutely immune from the attack of the termite.

Certain species of wood are said to be naturally highly resistant to the termite. According to Thomas E. Snyder, forest entomologist of the United States Department of Agriculture, teak (*Tectona grandis*) from Siam and Burma, greenheart (*Nectandra rodiae*) from South America and the West Indies, peroba (several species of *Aspidosperma*) from South America, and mahogany (*Swietena mahogani*) from tropical America seem to be immune from the attack of the North American termites.[3] Hagen also states that teak (*Tectona grandis*) and ironwood (*Sideroxylon*) of India are immune from attack by termites.[4] George P. Ahern, formerly director of the Philippine Bureau of Forestry, states that the following woods are not subject to attack by the *anay*, a native Philippine termite: *Dinglas* (*Eugenia bracteata* Roxb. var. *roxburghii* Duthie), *ipil* (*Intsia bijuga* Gray), *molave* (*Vitex littoralis* Dcne.), and *yacal* (*Hopea plagata* Vidal). In addition to these, *Cedrus deodar* from India, *Cedrus atlantica* from northern Africa, *Callitris glauca* (cypress pine) from Queensland, *Eucalyptus marginata* from Australia, and *Erythrophloeum lim* from Cochin China are reported to be immune from termite attack.

As a first step in the investigation it was necessary to prove whether these so-called immune timbers are really effective in preventing termite attack or not. To do this, forty-five species of native and exotic woods were selected and the test carried on as follows:

Method of investigation.—Each timber was cut into small blocks of definite size, 2 by 2 by 15 inches (about 5 by 5 by 38 centimeters); hundreds of these blocks were buried in the infested ground; different kinds of timbers were mingled, care being taken not to group the same species in one place; from time to time all the blocks were dug out for inspection, and after eliminating the infested ones the others were buried again.

Locality of the experiment stations.—Tainan, southern part of Formosa; and Matsubase, Kiushiu, Japan proper.

Materials.—The woods that were used are enumerated in Table VIII.

Result of the test at Tainan.—The ground was infested with *Odontotermes formosanus* (Shiraki), which is very common in the southern part of Formosa. The blocks were buried on November 17, 1912, and the final inspection was made on July 15, 1913.

[3] Bull. U. S. Bur. Ent. 94[2] (1916) 79.
[4] Monogr. Term. 10: 44, 45.

TABLE VIII.—*Scientific and English or local names of woods used in the experiments.*

PHILIPPINE WOODS.

No.	Scientific name.	English or local name.
1	*Intsia bijuga* O. Ktze.	Ipil.
2	*Pahudia rhomboidea* Prain	Tindalo.
3	*Albizzia acle* Merr	Acle.
4	*Wallaceodendron celebicum* Koord	Banuyo.
5	*Pterocarpus* sp	Red narra.
6	*Pterocarpus indicus* Willd	Yellow narra.
7	*Sindora supa* Merr	Supa.
8	*Aglaia clarkii* Merr	Tucang-calao.
9	*Toona calantas* Merr. et Rolfe	Calantas.
10	*Koordersiodendron pinnatum* Merr	Amuguis.
11	*Bombycidendron vidalianum* Merr. et Rolfe	Lanutan.
12	*Pometia pinnata* Forst	Malugay.
13	*Tarrietia sylvatica* Merr	Dungon.
14	*Calophyllum inophyllum* Linn	Palo maria.
15	*Shorea guiso* Blume	Guijo.
16	*Dipterocarpus grandiflorus* Blanco	Apitong.
17	*Homalium luzoniense* F.-Vill	Aranga.
18	*Sonneratia pagatpat* Blanco	Pagatpat.
19	*Eugenia* sp	Macaasim.
20	*Xanthostemon verdugonianus* Naves	Mancono.
21	*Palaquium philippense* C. B. Rob	Malacmalac.
22	*Illipe betis* Merr	Betis.
23	*Mimusops elengi* Linn	Bansalaguin.
24	*Wrightia laniti* Merr	Lanete.
25	*Vitex parviflora* Juss	Molave.

WOOD FROM COCHIN CHINA.

No.	Scientific name.	English or local name.
26	*Erythrophloeum lim* Max	Lim.

AUSTRALIAN WOODS.

No.	Scientific name.	English or local name.
27	*Callitris glauca* R. Br. (?)	Cypress pine.
28	*Eucalyptus saligna* Sm	Blue gum.
29	*Eucalyptus maculata* Hook	Spotted gum.
30	*Eucalyptus microcorys* F. Muell	Tallow wood.
31	*Eucalyptus pilularis* Sm	Black butt.
32	*Eucalyptus marginata* Sm	Jarrah.
33	*Eucalyptus resinifera* Sm	Red mahogany.
34	*Eucalyptus longifolia* Link et Otto	Wolly butt.
35	*Eucalyptus acmenioides* Schauer	White mahogany.
36	*Eucalyptus hemiphloia* F. Muell	Grey box.
37	*Eucalyptus eugenioides* Sieb	White stringy-bark.
38	*Eucalyptus propinqua* Deane et Maiden	Grey gum.
39	*Eucalyptus siderophloia* Benth	Iron bark.
40	*Syncarpia laurifolia* Tenn	Turpentine.

TABLE VIII.—*Scientific and English or local names of woods used in the experiments*—Continued.

INDIAN WOODS.

No.	Scientific name.	English or local name.
41	*Tectona grandis* Linn.	Teak.
42	Unknown	Kayil.
	WOOD FROM JAVA.	
43	Unknown	Jungle wood.
	NATIVE WOODS (FROM RIU KIU ISLANDS).	
44	*Podocarpus macrophylla* Don	Chaaki or bitotsuba.
45	*Bischofia javanica* Blume	Ikuki or akagi.

Result of the test at Matsubase.—The ground was infested by *Coptotermes formosanus* Shiraki. The experiment station was selected in Japan proper as well as in Formosa, in order to test the effect under different conditions, especially the effect by a different species of termite. The blocks were buried on February 11, 1913, and the first inspection was made on October 8, 1913, after two hundred forty-nine days.

Although the duration of the experiment was nearly the same at Tainan as at Matsubase, the results obtained were slightly different. Thus, in the latter locality, kayil, palo maria, and malacmalac were more seriously attacked; lim, tallow wood, iron bark, grey gum, white mahogany, supa, betis, pagatpat, calantas, malugay, lanete, bansalaguin, lanutan, banuyo, and grey box were less seriously attacked; red narra, guijo, yellow narra, white stringy-bark, acle, amuguis, tucang-calao, tindalo, batitinan, black butt, dungon, mancono, molave, and ipil, which have been attacked by *Odontotermes formosanus*, were immune. These differences seem to be due to the inactivity of the insect effected by somewhat lower temperature than in Formosa, as well as the existence of a smaller number of individuals. In order to get a more satisfactory result, the blocks that were found free from attack were buried again in the same place and left untouched until July 19, 1915.

Twenty-one months after first inspection, all the blocks were dug out. The results are shown in Table XI.

TABLE IX.—*Percentage of the damage to wood blocks by termites at Tainan.*

Name.	Origin.	Blocks.		Damage.
		Tested.	Infested.	
				Per cent.
Turpentine	Australia	3	3	100.00
Malugay	Philippines	20	18	90.00
Lanete	do	8	7	87.50
Jungle wood	Java	21	18	85.71
Supa	Philippines	21	18	85.71
Red narra	do	55	47	85.45
Red mahogany	Australia	24	20	83.33
Iron bark	do	29	24	82.76
Apitong	Philippines	27	22	81.88
Lim	Cochin China	43	35	81.40
Tallow wood	Australia	34	27	79.41
Grey box	do	39	30	76.92
Guijo	Philippines	21	15	71.43
White stringy-bark	Australia	27	19	70.37
Acle	Philippines	43	30	69.77
Amuguis	do	26	18	69.23
Lanutan	do	9	6	66.67
Tucang-calao	do	29	19	65.52
Calantas	do	40	26	65.00
Wolly butt	Australia	17	11	64.71
Chaaki	Riu Kiu	14	9	64.29
Ikuki	do	16	10	62.50
Yellow narra	Philippines	46	28	60.87
Betis	do	43	26	60.47
Batitinan	do	20	12	60.00
Tindalo	do	15	9	60.00
Pagatpat	do	20	12	60.00
Black butt	Australia	19	11	57.89
White mahogany	do	16	9	56.25
Bansalaguin	Philippines	25	14	56.00
Jarrah	Australia	11	6	54.55
Grey gum	do	16	8	50.00
Dungon	Philippines	44	20	45.45
Palo maria	do	28	12	42.86
Banuyo	do	51	20	39.22
Aranga	do	26	10	38.46
Malacmalac	do	25	9	37.50
Blue gum	Australia	3	1	33.33
Kayil	India	20	6	30.00
Mancono	Philippines	25	6	24.00
Macaasim	do	38	7	18.42
Molave	do	25	2	8.00
Ipil	do	25	1	4.00
Teak	India	50	0	0.00
Cypress pine	Australia	10	0	0.00

TABLE X.—*Percentage of the damage to wood blocks by termites at Matsubase.*

Name.	Origin.	Blocks. Tested.	Blocks. Infested.	Damage.
				Per cent.
Jungle wood	Java	10	10	100.00
Kayil	India	10	10	100.00
Palo maria	Philippines	9	8	88.89
Apitong	do	10	8	80.00
Jarrah	Australia	10	6	60.00
Malacmalac	Philippines	9	5	55.56
Lim	Cochin China	10	5	50.00
Calantas	Philippines	10	4	40.00
Aranga	do	10	3	30.00
Malugay	do	10	3	30.00
Lanete	do	4	1	25.00
Bansalaguin	do	9	2	22.23
Lanutan	do	5	1	20.00
Iron bark	Australia	10	2	20.00
Tallow wood	do	10	2	20.00
Grey gum	do	10	2	20.00
Macaasim	Philippines	10	2	20.00
White mahogany	Australia	10	2	20.00
Supa	Philippines	10	1	10.00
Betis	do	10	1	10.00
Pagatpat	do	10	1	10.00
Banuyo	do	10	1	10.00
Grey box	Australia	10	1	10.00
Red narra	Philippines	10	0	0.00
Guijo	do	10	0	0.00
Yellow narra	do	10	0	0.00
White stringy-bark	Australia	10	0	0.00
Acle	Philippines	10	0	0.00
Amuguis	do	5	0	0.00
Tucang-calao	do	10	0	0.00
Tindalo	do	5	0	0.00
Batitinan	do	10	0	0.00
Black butt	Australia	10	0	0.00
Dungon	Philippines	10	0	0.00
Mancono	do	10	0	0.00
Molave	do	10	0	0.00
Ipil	do	9	0	0.00
Teak	India	10	0	0.00
Cypress	Australia	5	0	0.00

TABLE XI.—*Wood blocks exposed to termites for twenty-one months.*

Attacked.	More or less attacked.		Entirely immune.
Calantas.	Tindalo.	Amuguis.	Molave.
Malugay.	Yellow narra.	Tucang-calao.	Ipil.
Lanete.	Guijo.	White stringy-bark.	Teak.
Bansalaguin.	Acle.	Black butt.	Cypress pine.
Lanutan.	Red narra.	Batitinan.	
Banuyo.	Dungon.	Mancono.	

These results agree quite well with those obtained at Tainan, although the Philippine woods molave and ipil have been slightly attacked by *Odontotermes formosanus.* It is a striking fact that teak and cypress pine, which are said to be absolutely immune from termites in the Tropics, are also free from the attack of two species of Formosan termites; namely, *Odontotermes formosanus* and *Coptotermes formosanus.* It seems reasonable, therefore, to conclude that teak and cypress pine are absolutely immune timbers.

The following paragraphs are quoted from Boulger: [5]

Cypress pine; *Callitris glauca* R. Br. (?); family Coniferae. Renowned for its pleasant odor—camphoraceous or sometimes reminding one of sandal-wood—and its great power of resistance to insect pests. Cypress pine is about the last timber that the white ant will attack. Some of the species, the red or black pine in particular, produce very showy timber; in fact, many of the planks are so gorgeous in appearance that care is required in using it for decorative purposes, lest it should have too overpowering an effect. At the same time much of the timber is of a quite, handsome character. The prevailing color of the figure is grown of various shades. It may be readily dressed to a smooth and glossy surface. It is extensively used in buildings liable to be attacked by white ants, for house blocks, linings, and ceilings of houses, and for telegraph poles. It is one of the most luxurious firewoods; it burns well, and in burning emits a delicious fragrance very generally admired. It is chiefly distributed in the drier parts of New South Wales, but some is available in the north coast district of Australia.

Teak; *Tectona grandis* L.; family Verbenaceae. It reaches a height of 80 to 100 feet, diameter 3 to 4 feet, sometimes larger. Trunk straight, leaves large, drooping, and deciduous, simple and opposite, with a dense mat of velvety hairs beneath, varying in size from 19–33 centimeters long, and 13.5–22 centimeters wide, though sprout leaves are much larger. Color of the timber is light straw-color to a brownish red, when fresh, but darkening on exposure. Some of the teak of the Decan is beautifully veined, streaked and mottled. Teak varies much according to locality and soil, that of Malabar being darker, heavier, and rather stronger, but not so large as that of Burma. Though without shakes on its outer surfaces, teak nearly always has a heartshake, which, owing to a twist in the growth, may often at the top be at right angles to what it is at the butt, thus seriously interfering with conversion, though often little affecting the use of the timber in bulk. In these shakes an excretion of apatite or phosphate of lime consolidates in white masses, which will turn the edge of most tools. Teak splits readily and is easily worked, but it owes its superiority for ship-building over both pine and oak in part to its freedom from any change of form or warping, when once seasoned, even under the extreme climatic variations. In India teak is used for railway sleepers, bridges, buildings and furnitures.

Teak is very fragrant when fresh and resembles rosewood, owing to an oleo-resin which also renders the wood probably the most durable of

[5] Boulger, G. S., Wood.

known timbers, making it obnoxious to termites and keeping off rust from iron in contact with it. Seasoned teak has, however, a very unpleasant smell, which has been compared to that of old shoe-leather. It is distributed in India, Burma, Siam, Ceylon, Java, Sumatra, and Celebes. In the Philippines small plantations occur in the southern islands, especially in Zamboanga district, Basilan Island.

RELATIONSHIP BETWEEN THE RESISTANCE AND THE PHYSICAL PROPERTIES OF TIMBER

It has been proved that some timbers are more highly resistant to termite attack than others; or, in other words, durability of timber seems to be effected by its physical or chemical properties. Determination of the factor of resistance is highly important in order to discover the preventive measures against termites. Therefore, the relation of the physical properties of timbers to the resistance is considered first.

TABLE XII.—*Relationship between resistance and hardness of various woods.*

Wood.	Degree of hardness.	Damage.
		Per cent.
Ipil	Hard	4.00
Molave	do	8.00
Macaasim	do	18.42
Mancono	Very hard	24.00
Aranga	do	38.46
Banuyo	Moderately hard	39.22
Palo maria	Hard	42.86
Dungon	Very hard	45.45
Bansalaguin	do	56.00
Tindalo	Hard	60.00
Batitinan	do	60.00
Pagatpat	do	60.00
Betis	Very hard	60.47
Yellow narra	Moderately hard	60.87
Calantas	Soft	65.00
Tucang-calao	Hard	65.62
Amuguis	do	69.23
Acle	do	69.77
Guijo	do	71.43
Red narra	Moderately hard	85.45
Supa	Hard	85.71
Malugay	do	90.00

Tables XIII and XIV are based mainly on the work of Gardner.[6] The result of the test obtained at Tainan is adopted in the tables to indicate the percentage of the damage.

[6] Bull. Philip. Bur. Forest. 4 (1907).

TABLE XIII.—*Relationship between resistance and weight of various woods.*

Wood.	Degree of weight.	Damage.
		Per cent.
Ipil	Heavy	4.00
Molave	do	8.00
Macaasim	do	18.42
Mancono	Very heavy	24.00
Aranga	Heavy	33.46
Banuyo	Moderately heavy	39.22
Palo maria	do	42.86
Dungon	Heavy	45.45
Bansalaguin	do	56.00
Batitinan	do	60.00
Pagatpat	do	60.00
Tindalo	do	60.00
Betis	do	60.47
Yellow narra	Moderately heavy	60.87
Calantas	Light	65.00
Amuguis	Heavy	69.23
Acle	do	69.77
Guijo	do	71.43
Apitong	do	81.88
Red narra	do	85.45
Lanete	do	87.50
Malugay	do	90.00

TABLE XIV.—*The weights of woods of various specific gravities.*

	Specific gravity.	Per cubic meter.	Per cubic foot.
		Kilos.	*Lbs.*
Very heavy	90 or +	900 or +	56 or +
Heavy	70 to 90	700 to 900	44 to 56
Moderately heavy	50 to 70	500 to 700	31 to 44
Light	50 or —	500 or —	31 or —

As shown in Table XII, mancono and aranga, which are included in the group "very hard," are more seriously attacked than ipil, molave, and macaasim of the group "hard;" banuyo is less attacked than harder woods, such as palo maria, tindalo, etc.; calantas, a soft wood, is also less attacked than tucang-calao, amuguis, acle, etc., which belong to the group "hard."

Table XIII shows that ipil, molave, and macaasim, which are included in the group "heavy," are less attacked than very heavy mancono; that dungon, bansalaguin, batitinan, etc., are more seriously attacked than banuyo and palo maria of the group "moderately heavy;" and that amuguis, acle, guijo, etc., are also more seriously attacked than calantas, a light wood.

Thus the durability or resistance of timbers to the attack of termites is not effected by hardness or weight; that is, the immunity of timbers is not due to their physical properties.

RELATIONSHIP BETWEEN THE RESISTANCE AND THE CHEMICAL PROPERTIES OF TIMBER

Snyder[7] states that the immunity or relative resistance of ironwood is not due to hardness—since Asiatic termites attack the hardest wood, lignum-vitæ—but to the presence in the wood of a substance (oils or alkaloids) repellent or distasteful to termites. He also states that the presence of tyloses or of gums may be factors in determining the durability and resistance of hardwood species. It has been proved that the physical properties of woods are not the real factor of resistance as suggested by that author. However, another suggestion of Snyder, that the presence of certain chemical substances in woods is the true factor, is somewhat dubious. As he gives no data in detail, it is hard to understand what are the principal ingredients and how they act in preventing the damage.

In order to determine the relationship between the resistance and the chemical properties of woods, I made the following investigation:

The quantity of ash and benzene extract in the above-mentioned woods was measured and compared with the percentage of damage obtained at Tainan.

Sampling.—A block of wood is cut along the three planes crossed at right angles, and the sawdust is collected. By the diagonal method reduction of the amount of the sample is made repeatedly, until about 20 grams of the sawdust are obtained. This sample is exposed for one hour in an air bath at 105° to 110° C. Then it is kept in a desiccator as a representative sample.

Method of estimation of ash.—A 1-gram sample is heated to redness in a platinum crucible over a Bunsen burner, and the incombustible substances are brought to a constant weight.

Method of estimation of benzene extract.—To estimate the benzene extract 5.00 grams of the sample are put into a Soxhlet apparatus and extracted with pure benzene for from six to ten hours. The benzene is driven off on a water bath, and afterwards the container is heated in an air bath at 120° C. to a constant weight. All determinations are made in duplicate.

[7] Bull. U. S. Bur. Ent. 94 (1916) 79, 80.

TABLE XV.—*Amount of ash and benzene extract in various woods.*

Name of wood.	Origin.	Damage.	Ash.	Benzene extract.
		Per cent.	*Per cent.*	*Per cent.*
Cypress pine	Australia	0.00	1.51	5.98
Teak	India	0.00	2.96	6.22
Ipil	Philippines	4.00	1.37	0.68
Molave	do	8.00	2.97	2.60
Macassim	do	18.42	1.54	2.31
Mancono	do	24.00	2.58	0.004
Kayil	India	30.00	2.00	3.80
Malacmalac	Philippines	37.50	1.43	3.37
Aranga	do	38.46	4.25	0.01
Banuyo	do	39.22	0.75	0.15
Palo maria	do	42.86	2.65	2.93
Dungon	do	45.45	5.26	0.79
Grey gum	Australia	50.00	0.74	0.53
Jarrah	do	54.55	1.00	2.65
Bansalaguin	Philippines	56.00	1.77	0.05
White mahogany	Australia	56.25	0.33	0.55
Black butt	do	57.89	0.42	0.05
Pagatpat	Philippines	60.00	3.74	0.27
Tindalo	do	60.00	2.30	1.99
Batitinan	do	60.00	6.43	2.43
Betis	do	60.47	2.25	0.06
Yellow narra	do	60.87	1.87	2.23
Ikuki	Riu Kiu	62.50	1.70	0.37
Chaaki	do	64.29	1.61	0.36
Wolly butt	Australia	64.71	1.05	0.14
Calantas	Philippines	65.00	1.82	1.50
Tucang-calao	do	65.52	2.44	2.19
Lanutan	do	66.67	2.99	0.44
Amuguis	do	69.23	2.41	1.79
Acle	do	69.77	1.31	1.51
White stringy-bark	Australia	70.37	0.62	0.16
Guijo	Philippines	71.43	1.96	1.13
Grey box	Australia	76.92	0.78	0.40
Tallow wood	do	79.41	0.51	1.68
Lim	Cochin China	81.40	0.23	2.22
Apitong	Philippines	82.76	0.77	0.004
Red mahogany	Australia	83.33	0.58	0.26
Red narra	Philippines	85.45	1.36	3.80
Supa	do	85.71	1.56	0.80
Jungle wood	Java	85.71	3.07	0.11
Lancte	Philippines	87.50	2.04	0.002
Malugay	do	90.00	3.13	0.13

From Table XV it is evident that no special relationship exists between the resistance and the amount of ash and benzene extract. It is rather striking, however, that the percentage of benzene extract contained in cypress pine and teak, which are absolutely immune from the attack, is extraordinarily high. As it is probable that some organic compounds extracted by benzene are distasteful or repellent to termites, determination of the

chemical properties of these extracts has been made as shown in the following pages.

THE VOLATILE CONSTITUENTS OF CYPRESS PINE

[The following is based mainly on the work by Kinzo Kafuku,[9] former expert chemist of the Government Institute of Science, Formosa.]

A block of cypress pine weighing 36 kilograms is sliced into thin pieces and placed in a large extractor. After extracting for three days continuously, using 90 per cent alcohol, the alcohol is distilled off, and by means of steam distillation the light and the heavy oils are separated from the resinous substances. Upon cooling delicate needle-shaped crystals appear in the heavy oil. Because of their viscous nature, it is very hard to separate the oils from the water by filtration. Therefore, a proper quantity of ether is added in order to transfer the oils to that layer. After separating the layer of ether with a separatory funnel, ether is eliminated by distillation. Then that which remains is heated under low pressure (30 millimeters), and the ether and water are completely driven off. Thus, 375 grams of the sample (1.04 per cent per kilogram of wood) are obtained. Alcohol, instead of benzene, is used as a solvent because it is more economical and has the same power of extraction in this case.

Crude oil.—The crude oil extracted from cypress pine is a viscous substance having a greenish brown tinge and a slight acid reaction; it evaporates at 280° C. under ordinary pressure.

TABLE XVI.—*Properties of the crude oil from cypress pine.*

Specific gravity (at 17° C.)	1.002
Refractive index (at 20° C.)	1.5084
Optical rotatory power ($[\alpha]^D$ in 20 per cent ethyl alcohol) (degrees)	+18
Acid value	18.13
Ester value	51.50
Ester value after acetylation	196.1

These ester values indicate the presence of about 90 per cent of alcohol ($C_{15}H_{26}O$).

The result of the elemental analysis is as follows:

0.1863 gram crude oil gave 0.5473 gram CO_2 and 0.1849 gram H_2O.

	Required for $C_{15}H_{26}O$. Per cent.	Found. Per cent.
C	81.08	80.12
H	11.71	11.11

Besides this, the existence of the ester (15 per cent) and of phenol (10 per cent) is also proved. But as the percentages

of these two are not high, it is probable that the main part of the oil consists of a group of sesquiterpene alcohols.

Fractionation of the neutral oil.—Two hundred grams of 50 per cent aqueous solution of sodium hydroxide are added to 100 grams of the crude oil, and the mixture is shaken for two hours. Then ether is added in order to separate the oil from the solution. Eliminating the ether, the neutral oil is obtained free from acid and phenol. About 80 per cent of the crude oil is neutral oil having the following properties:

TABLE XVII.—*Properties of the neutral oil from cypress pine.*

Specific gravity (at 10°C.)	1.009
Refractive index (at 19°C.)	1.5090
Optical rotatory power ($[\alpha]^D$ in 20 per cent ethyl alcohol) (degrees)	+19.5
Ester value	33.75
Ester value after acetylation	162.5

These ester values indicate the presence of about 56 per cent of alcohol ($C_{15}H_{26}O$) in the neutral oil.

This oil evaporates at 120° C. under reduced pressure (4 millimeters), thus indicating more clearly the presence of sesquiterpene alcohol.

The result of a fractional distillation of a 50-gram sample of the neutral oil is shown in Table XVIII.

TABLE XVIII.—*Fractions obtained from the neutral oil of cypress pine.*

Distilling point; pressure, 4 mm.	Yield.	
°C.	*Grams.*	*Per cent.*
115 to 119	11	18.0
119 to 125	23	37.7
125 to 135	2	3.3
135 to 145	7	11.5
145 to 170	6	9.8

The fractional distillation is repeated three times; and, finally, the results recorded in Table XIX are obtained.

TABLE XIX.—*Final fractions from the neutral oil of cypress pine.*

Distilling point; pressure, 3.5 mm.	Yield.	Refractive index.	Rotation $[\alpha]$ D
°C.	*Grams.*		*Degrees.*
110 to 115	7	1.5045	+10
115 to 122	16	1.5066	+10.5
122 to 128	11	1.5082	+21.1
128 to 142	9	1.5095	+24.6
142 to 165	6	1.5128	+36.4

The first fraction is pale green and less viscous, while the second and third are rather sticky, yellowish in color, and gradually crystallize when fed with a piece of the crystals obtained from the crude oil.

It is obvious that the main part of the neutral oil consists of the second and third fractions, the principal ingredient of which is the same substance as that crystallized from the crude oil.

Five grams of the crude oil are placed on the surface of an absorptive porcelain plate. When the oil is entirely absorbed, the crystals are dissolved in absolute alcohol, and the solution is diluted with one-fourth its volume of water and filtered. The precipitate thus obtained is recrystallized from 70 per cent alcohol and dried.

The melting point of these crystals is 91.2° to 91.5° C. An elemental analysis indicates that these crystals are a compound belonging to the sesquiterpene alcohols.

0.0995 gram of crystals gave 0.2926 gram CO_2 and 0.1046 gram H_2O.

	Required for $C_{15}H_{26}O$. Per cent.	Found. Per cent.
C	81.08	80.20
H	11.71	11.66

The optical rotatory power of this substance dissolved in chloroform is −30°, approximately that of guajol (−29.8°), which belongs to the sesquiterpene alcohols. Testing many other important chemical reactions, Mr. Kafuku came to the conclusion that the crystal is nothing but guajol.

An elemental analysis of the first fraction of the neutral oil is carried on; and it is proved that the fraction also consists of a sesquiterpene alcohol, although it does not contain the crystal.

0.1194 gram of crystals gave 0.3504 gram CO_2 and 0.1206 gram H_2O.

	Required for $C_{15}H_{26}O$. Per cent.	Found. Per cent.
C	81.08	80.08
H	11.71	11.30

Phenol and acid.—The neutral oil which is separated from sodium hydroxide solution is washed with an aqueous solution of sodium chloride. The sodium chloride and the sodium hydroxide solutions are mixed; acids and phenols which are contained in this solution are separated by 5 *N* sulphuric acid and extracted three times with ether. The ether solution is treated three times with 5 per cent solution of sodium bicarbonate in order to separate the acids from the phenols. It is estimated

that the crude oil contains 7 per cent phenols and 10.5 per cent of acids. The result of a fractional distillation of the acids is given in Table XX.

TABLE XX.—*Fractional distillation of the acids.*

Distilling point; pressure, 3 mm. °C.	Yield. Per cent.
115 to 155	38
155 to 175	30
Residue	30

These acids seem to belong to the fatty acids. But at present nothing can be said about their chemical properties.

Baker and Smith[8] made an investigation of the phenol, and the name callitrol has been proposed for it. As these authors did not give the data in detail, it is hard to identify this phenol. However, the color reaction briefly stated by them is indicated in the phenol obtained by the above-mentioned method. It is reasonable, therefore, to treat the present phenol as callitrol. The result of a fractional distillation of the phenol is given in Table XXI.

TABLE XXI.—*Fractional distillation of the phenol.*

Distilling point; pressure, 4 mm. °C.	Yield. Per cent.
125 to 135	15
135 to 155	7
155 to 165	48
Residue	30

According to the statement by Mr. Kafuku, the presence of eugenol in the first fraction is undeniable. He states also that the empirical composition of the third fraction approximates $C_{13}H_{28}O_2$.

As shown, the volatile constituent of cypress pine is mainly guajol, a sesquiterpene alcohol, which is said to be highly antiseptic. In order to prove the effect of this oil practically, the crude oil separated from resinous substances was dissolved in alcohol and injected into Japanese pine, which is most liable to the attack of termites. After entirely evaporating the alcohol, the treated blocks were buried in ground infested by *Coptotermes formosanus.* Although the controls, that is, untreated wood specimens, were seriously attacked within only one week, the treated ones were not attacked during one year (Plate XI, fig. 2, *a*, *b*).

[8] Baker, Richard T., and Smith, Henry G., A research on the pines of Australia. Technological Museum, New South Wales (1910) 63.

Such being the case there is no doubt that the volatile constituents of cypress pine are effective in preventing the attack of termites.

SUMMARY

1. Cypress pine contains about 1 per cent of volatile constituents.
2. The volatile constituents are effective in preventing the attack of termites.
3. The principal ingredient of the volatile constituents is guajol, which is said to be highly antiseptic. The oil contains about 60 per cent of guajol.
4. The volatile constituents of cypress pine contain a small amount of unknown acids and phenol. The latter seems to be callitrol.

THE VOLATILE CONSTITUENTS OF TEAK

In 1887 Romanes [9] made an investigation on the volatile constituents of teak. According to his statement the alcohol extract of teak does not contain volatile oils, but consists mainly of resinous substances. By means of distillation an amber-colored crystal, which he named tectoquinone ($C_{18}H_{16}O_2$), was separated from the resinous substances. It is reported to be soluble in alcohol and melts at 171° C. When it is reduced with zinc powder and acetic acid, a hydrocarbon $C_{18}H_{22}$ is obtained.

In order to test this statement, 600 grams of sliced teak were extracted with alcohol. By means of steam distillation a fine, amber-colored crystal was separated from the extract. It is more or less soluble in water. When it is recrystallized from a dilute alcohol solution, it separates into two parts; one part is pale yellow, while the other is deep yellow. At present nothing can be said about the nature of this crystal nor of the resinous substances, because the materials at hand were insufficient to continue the investigation.

THE VOLATILE CONSTITUENTS OF FOOCHOW CEDAR AND RANDAI CEDAR

In 1916 at Foochow, South China, I found that the Chinese people were using Foochow cedar (*Cunninghamia sinensis* R. Br.) as the principal building material, claiming that the timber is highly resistant to termite attack. It is certain, however, that the immunity of Foochow cedar is not absolute, because the Chinese houses in Formosa are attacked by the termite, although they are mainly constructed of Foochow cedar.

As a result of inspection of many infested buildings in Foochow I came to the conclusion that the heartwood of Foochow

[9] Proc. Chem. Soc. London (1887) 4–116.

cedar is somewhat resistant, for the damage was less when heartwood was used than when sapwood was used. When freshly cut the heartwood is reddish in color and emits a pleasing fragrance like camphor, while the sapwood is whitish and odorless. It is possible, therefore, that the resistance of the heartwood is due to the presence of some antiseptic chemical. Led by the supposition, an investigation to determine the chemical properties of Foochow cedar was made.

Fresh Foochow cedar, from Foochow (235 pounds, or 106.5+ kilograms), was cut into thin slices and extracted by means of steam distillation. Superheated steam (pressure, 40 pounds, or 18+ kilograms) was passed through the extractor (capacity, 50 pounds, or 22+ kilograms) for five hours, and the vapor was condensed in a copper condenser. The oil layer floating on the water was separated by a separatory funnel. From this 650 grams (4.6 per cent) of viscous, grayish brown oil were obtained. On cooling the oil a large amount of fine, needle-shaped crystals formed. After keeping the oil at 5° C. for twenty-four hours, it was filtered in order to separate the crystals. Crystals thus obtained were placed on an absorptive porcelain plate and entirely freed from oil. One hundred one grams of pure white crystals (nearly 40 per cent of the oil) were obtained. These crystals are soluble in ether, chloroform, petroleum ether, and amyl alcohol and are easily recrystallized from methyl alcohol solution. By means of sublimation under ordinary pressure the substance changes into colorless, delicate crystals, having the appearance of asbestos. The oil separated from the crystals has the properties recorded in Table XXII.

TABLE XXII.—*Properties of oil from Foochow cedar.*

Optical rotatory power ($[^a]$ D in 10 per cent benzene solution) (degrees)	+7.74
Refractive index (at 28° C.)	1.4970
Specific gravity (at 18.5° C.)	0.9465
Acid value	0.0
Ester value	9.37
Ester value after acetylation	57.20

According to the results of an investigation made by K. Kafuku, the present oil contains only 2 per cent of alcohol ($C_{10}H_{18}O$). The presence of nopinene, camphene, and borneol is also proved by that author.[10] Under ordinary pressure it distills at 160° C. Below 310° C. the fractions are colorless,

[10] Report of the termite 6 (1917) 57–91.

while above that temperature they are yellowish and become highly viscous.

The crude crystals separated from the oil were dissolved in absolute alcohol and forty-three parts of water were added. Then the solution was cooled in order to precipitate the crystals. Under atmospheric pressure it was sublimated again, and the pure crystals were obtained.

I. 0.2319 gram of crystals gave 0.6822 gram CO_2 and 0.2442 gram H_2O.
II. 0.2159 gram of crystals gave 0.6381 gram CO_2 and 0.2268 gram H_2O.

	Required for $C_3H_{20}O$. Per cent.	Found. Per cent. I.	Found. Per cent. II.
C	81.08	80.23	80.61
H	11.71	11.69	11.76

These percentage numbers agree quite well with those of sesquiterpene alcohol. The molecular weight of the crystals (231 to 234) also approximates that of the sesquiterpene alcohol (222). Such being the case, there is no doubt that the crystalline substance contained in Foochow cedar is a sesquiterpene alcohol.

Mr. K. Kafuku studied this crystal in detail and expressed the view that cedrol, a sesquiterpene alcohol that has been extracted from red cedar (*Juniperus virginiana* L.), is the same substance.

TABLE XXIII.—*Comparison of Foochow cedar crystals with cedrol.*

	Foochow cedar crystals.	Cedrol.
Melting point .... °C..	86	86 to 87
Boiling point .... °C..	292 to 294	291 to 294
Optical rotatory power .... degrees..	[a] +10.9	[b] +9.5

[a] In 10 per cent chloroform solution. [b] In 11.3 per cent chloroform solution.

Cedrol, the principal ingredient of Foochow cedar oil, is not identical with guajol. It is a striking fact, however, that both cypress pine and Foochow cedar, which are said to be highly resistant to the attack of termites, contain antiseptic compounds that belong to the same group, the sesquiterpene alcohols.

Besides Foochow cedar, another species is contained in the genus *Cunninghamia*. A few years ago, Dr. B. Hayata described this species from Formosa, giving it the name *Cunninghamia konishii*. At present it is not known whether it is resistant to the attack of termites or not; but, as it is very closely allied to

Foochow cedar, an investigation of its chemical properties was made.

Some fine, fresh material was forwarded by the authorities of the Bureau of Forestry, from the mountain in Giran. It was treated in the same way as Foochow cedar, being cut into thin pieces and extracted by means of steam distillation. It is rather striking that exactly similar oil and crystals were obtained from Randai cedar and from Foochow cedar. However, the percentage of the oil in Randai cedar, 1.62 per cent, differs slightly from that in Foochow cedar, 4.6 per cent.[11]

STUDIES ON CAMPHOR GREEN OIL

[The following is a result of the joint work of M. Oshima, naturalist, and Kinzo Kafuku, former expert chemist, of the Government Institute of Science, Formosa.]

As shown in the preceding pages, a sesquiterpene alcohol ($C_{15}H_{26}O$) seems to be one of the chemicals that are effective in preventing the attack of termites. It is highly expensive to import cypress pine or other immune timbers for the sake of building ordinary houses. Moreover, it is almost impossible to get a sufficient quantity of guajol or cedrol for use in conferring immunity upon nonresistant timbers. Under these circumstances the work was extended to discover some home product from which sesquiterpene alcohol could be obtained. As a first step camphor oil was investigated, because the heavy oil of this is greenish and viscous like the oil extracted from cypress

[11] Foochow cedar; *Cunninghamia sinensis* R. Br. Trunk 10 to 15 meters tall, branches whorled. Leaves very densely and alternately arranged, distichous, coriaceous, 3 to 7 centimeters long, 5 to 7 millimeters broad, linear-lanceolate acuminate, slightly serrulate at the margin, polished above, dull below. Male flower 10 to 15 millimeters long, 3 to 4 millimeters broad, yellow. Cone 3 to 4 centimeters long and broad; middle scale 15 to 18 millimeters long and wide; seeds 6 to 7 millimeters long, 5 to 6 millimeters broad, very complanate, surrounded by a small wing.

Randai cedar; *Cunninghamia konishii* Hayata. Trunk tall, branches terete, glabrous. Leaves linear falcate, acute, slightly carinate on the back, lanceolate, 15 millimeters long, 2.5 millimeters broad, slightly obtuse at the apex, slightly serrulate at the margin, coriaceous, slightly glaucous. Cone ovately globose, 20 centimeters long, 15 millimeters broad. Scales rounded. Seeds very small, ovately elliptical, surrounded by a small wing.

The grain of Randai cedar is finer than that of Foochow cedar. When freshly cut it emits a sweet fragrance. The heartwood has a dark reddish color. At present it is hard to find this wood in the market, but the Bureau of Forestry of the Government of Formosa plans to supply it as a building material in Formosa in the near future.

pine and it was thought to be possible to establish the identity of guajol and cedrol.

Camphor oil.—Camphor oil is obtained from camphor wood (*Cinnamomum camphora* Nees et Ebermeyer). A trunk of this wood is chopped up and the slices (each piece about 30 to 40 grams) are extracted by means of steam distillation. The mixture of steam and camphor vapor is led to a series of wooden condensers. As soon as it is cooled with running water, crystals of camphor are sublimated under the cover of the condenser and a layer of oil appears floating on the surface of the water. When the oil is cool, the remainder of the camphor is deposited and roughly separated from the oil. These operations are carried on in a camp in the mountains.

The crude camphor oil thus obtained is a yellow or dark yellow fluid and emits the characteristic odor of camphor, thus proving the presence of the crystals of camphor (specific gravity, 0.950 to 0.995 at 15° C.). Under ordinary atmospheric pressure it distills at from 150° to 270° C., yielding *d*-pinene, camphene, cineol, limonene, camphor, and safrol.

In the factory of the Monopoly Bureau of the Government of Formosa, the crude camphor oil is refined and separated into the following fractions:

	Specific gravity.
White oil	0.87 to 0.91
Mother liquid of camphor	0.91 to 0.99
Red oil	0.99 to 1.035

It is proved that the residue contains a certain amount of safrol. Therefore, the residue is distilled again under low pressure (200 millimeters) in order to eliminate a fraction which contains a considerable amount of safrol (specific gravity, 1.00 to 1.04). In the beginning of this operation the specific gravity increases gradually. After reaching a constant, it decreases gradually, showing a number less than 1.00. The oil, the specific gravity of which is less than 1.00, is a green or deep blue, viscous fluid and is called camphor green oil (specific gravity, about 0.98; refractive index, about 1.5). Under ordinary atmospheric pressure it distills at 210° to 300° C., leaving 3 per cent of pitch.

Physical and chemical properties of camphor green oil.—The samples for the determination of the physical and chemical properties of camphor green oil were supplied by the Monopoly Bureau of the Government.

TABLE XXIV.—*Physical and chemical properties of camphor green oil.*

[Poiseuille's capillary viscosimeter modified by Ostwald was used in the determination of viscosity.]

SAMPLE A.

Color	Dark Brown.
Specific gravity (at 15° C.)	0.9805
Refractive index (at 17.5° C.)	1.5035
Optical rotatory power	Unknown.
Viscosity (at 20° C.)	1.38
Fractional distillation (ordinary atmosphere pressure):	Per cent.
Below 210	1.0
210 to 230	26.0
230 to 240	23.0
240 to 260	25.0
260 to 300	22.0
Residue	3.0

SAMPLE B.

Color	Greenish brown.
Specific gravity (at 20° C.)	0.984
Refractive index (at 20° C.)	1.504
Optical rotatory power	Unknown.
Viscosity (at 20° C.)	1.67
Fractional distillation:	Per cent.
Below 210	1.0
210 to 230	10.0
230 to 240	26.0
240 to 260	25.0
260 to 300	35.0
Residue	3.9

SAMPLE C.

Color	Yellowish brown.
Specific gravity (at 20° C.)	1.00
Refractive index (at 20° C.)	1.511
Optical rotatory power	+; degree unknown.
Viscosity (at 20° C.)	1.83
Fractional distillation:	Per cent.
Below 210	0.5
210 to 230	2.0
230 to 240	6.0
240 to 260	42.0
260 to 300	44.0
Residue	4.0

TABLE XXIV.—*Physical and chemical properties of camphor green oil*—Ctd.

SAMPLE D.

Color	Greenish brown.	
Specific gravity (at 20° C.)	0.981	
Refractive index (at 20° C.)	1.503	
Optical rotatory power	+; degree unknown.	
Viscosity (at 20° C.)	1.60	
		Per cent.
Fractional distillation:		
Below 210		0.7
210 to 230		14.0
230 to 240		22.5
240 to 260		27.0
260 to 310		32.0
Residue		3.0

The fractional distillation of sample A has been carried on and the fractions thus obtained have been used in further investigation. It has been distilled under reduced pressure (50 to 55 millimeters) to prevent decomposition.

Acid and ester value of camphor green oil.—Two grams of the sample are neutralized with 0.5 *N* alcoholic solution of potassium hydroxide, using phenolphthalein as an indicator. After adding 25 cubic centimeters of the same solution, it is refluxed on a water bath for twenty minutes. Adding 0.5 *N* solution of sulphuric acid, the ester value is estimated. Ester value, 0.66.

Some 0.1 *N* solution of potassium hydroxide is added to 25 grams of the sample, and its acid value is estimated.

Sample.	Acid value.
B	3.14
C	5.49
D	2.58

PRINCIPAL CONSTITUENTS OF CAMPHOR GREEN OIL

Acid and phenol.—Besides caprylic acid and $C_9H_{16}O_2$, which are known as the constituents of camphor green oil, the presence of the following acids has been newly proved:

Methylene-ether-3,4-dioxybenzene-1-carboxylic acid ($C_8H_6O_4$).
Lauric acid ($C_{12}H_{24}O_2$).
An unknown acid.

The green oil contains about 1.5 per cent of phenols. The composition of this phenolic mixture is highly complicated; at present the presence of eugenol and carvacrol only has been proved.

Aldehyde and ketone.—The percentage of aldehyde and ketone

in the camphor green oil is less than 0.04. The presence of the following has been proved:

Δ_1-Menthenone-3 (melting point, 224° C.).
Cumic aldehyde semicarbazone (melting point, 210° C.).
An unknown semicarbazone (melting point, 218° C.).

Camphor and cineol.—As a result of the fractional distillation it is proved that camphor green oil still contains camphor (8.1 per cent). The presence of cineol and limonene is a well-known fact.

Safrol.—In the fractions distilled at comparatively low temperature crystals of safrol are deposited. It is proved that the oil contains about 30 per cent of safrol.

Terpene alcohol.—It is possible to find linarol, garaneol, citroneol, terpineol, *d*-terpineol, and cumic alcohol. The presence of these compounds has not been actually proved, because an important reagent, phenylisocyanate, was not at hand.

Sesquiterpene and sesquiterpene alcohol.—It is proved by K. Kafuku that camphor green oil contains about 10 per cent of sesquiterpenes (cadinene, bisabolene, and sesquicamphene) and 25 per cent of sesquiterpene alcohol. He took three fractions (115° to 120°, 120° to 130°, 130° to 140° C.) distilled under reduced pressure (5 millimeters) and redistilled them, adding metallic sodium. The refractive indices are given in Table XXV.

TABLE XXV.—*Refractive indices of the three fractions distilled under reduced pressure.*

Distilling point. °C.	Refractive index at 18 °C.
120 to 125	1.4980
125 to 130	1.4998
130 to 135	1.5032
135 to 140	1.5050

Elemental analyses of these fractions have been made by Kafuku, proving that some of the fractions consist entirely of sesquiterpene alcohol as shown in the following:

0.1652 gram of the material gave 0.4920 CO_2 and 0.1655 H_2O.

	Required for $C_{15}H_{26}O$. Per cent.	Found. Per cent.
C	81.08	81.23
H	11.71	11.74

This sesquiterpene alcohol is not a crystal like guajol or cedrol, but is a colorless, viscous fluid, sometimes giving a pale green color.

TEST OF THE RESISTANCE OF CAMPHOR GREEN OIL TO TERMITE ATTACK

As supposed in the beginning, camphor green oil really contains sesquiterpene alcohol, which is said to be effective in preventing the attack of termites. In order to prove its effect practically, the following tests were carried on:

Experiment 1.—Camphor green oil, roughly fractionated in the Monopoly Bureau, was injected into Japanese pine by means of full process. The blocks (2 by 2 by 15 inches, or about 5 by 5 by 38 centimeters) were buried in ground infested by *Coptotermes formosanus* with several control pieces (untreated pine). The controls were seriously attacked within five to seven days (Plate XI, fig. 2, *a*, *b*), while the treated blocks remained unattacked for about one year (Plate XI, fig. 2, *c*).

It is obvious that camphor green oil is effective in preventing the attack of termites. However, it is very expensive, if the pure oil is used. As shown in Table XXVI, the amount of oil produced in the Monopoly Bureau is not sufficient for treating all the timbers used in Formosa.

TABLE XXVI.—*Camphor green oil produced by the Monopoly Bureau.*

Year.	Pounds.
1912	44,562
1913	23,491
1914	28,397

Containing only 1.04 per cent of volatile oil, cypress pine is highly resistant to termites. Foochow cedar, more or less resistant to termites, contains 4.6 per cent of volatile oil. It seems reasonable to expect, therefore, that a small amount of the camphor green oil may be effective in preventing damage. If this is true, we can economize the green oil by using a small amount, instead of a large quantity as in the case of creosoting (5 to 6 gallons per cubic foot, or 18 to 22 liters per 0.028+ cubic meter, of timber).

To use the camphor green oil practically, it is necessary to employ a method of treating timbers at the lowest expense, injecting only a small amount of the oil. In order to determine the limit of the amount of oil that is effective in preventing damage, the following experiment was made:

Experiment 2.—Camphor green oil was dissolved in 90 per cent ethyl alcohol, making 1, 2, 3, 5, and 10 per cent solutions. After injecting each solution into Japanese pine (2 by 2 by 15 inches, or about 5 by 5 by 38 centimeters), the alcohol was

evaporated by exposing the blocks to direct sunlight. Thus, a considerable number of blocks of pine containing different amounts of the oil was prepared.

The treated blocks were buried in ground infested by *Coptotermes formosanus*. From time to time they were dug out for inspection, and only the unattacked samples were buried again. This experiment was carried on for nearly two and a half years.

TABLE XXVII.—*Blocks of Japanese pine treated with solutions of camphor green oil.*

[Experiment station, Shakko, near Taihoku. Experiment started August 5, 1914. Blocks inspected March 7, 1915; August 8, 1915; August 28, 1916; and March 24, 1917.]

Inspected.	Blocks.			Damage.
	Total.	Infested.	No damage.	Per cent.
1 PER CENT SOLUTION.				
March 7, 1915	39	39	0	100
2 PER CENT SOLUTION.				
March 7, 1915	62	55	7	89
August 8, 1915	7	1	6	90
August 28, 1916	6	2	4	94
March 24, 1917	6	0	6	94
3 PER CENT SOLUTION.				
March 7, 1915	67	51	16	76
August 8, 1915	16	9	7	90
August 28, 1916	7	0	7	90
March 24, 1917	7	0	7	90
5 PER CENT SOLUTION.				
March 7, 1915	59	11	48	19
August 8, 1915	48	15	33	44
August 28, 1916	33	3	30	49
March 24, 1917	30	2	28	53
10 PER CENT SOLUTION.				
March 7, 1915	67	5	62	7
August 8, 1915	62	19	43	36
August 28, 1916	43	1	42	37
March 24, 1917	42	6	36	46

With the control, blocks injected with pure Niizu neutral oil, the results shown in Table XXXII were obtained.

TABLE XXXII.—*Japanese pine blocks injected with pure Niizu neutral oil.*

Total blocks	4
Damaged:	
Number	2
Per cent	50
Dry rot:	
Number	2
Per cent	50

Notwithstanding the fact that Japanese pine is most liable to the attack of termites, the blocks treated with the neutral oil remained unattacked after the lapse of more than two years. As the controls were attacked by the termite and fungus as well, it is clear that the green oil is an essential factor in preventing the damage. The mixture of Niizu neutral oil and the green oil (10 per cent solution) costs about 5 cents per gallon. Its color is pale yellow, and it gives no stain to timbers; its odor is pleasant, being similar to the characteristic fragrance of camphor; it is nonpoisonous to human beings; it is not volatile under ordinary temperature. Thus, this solution seems satisfactory as a preventive against the attack of termites.

Volatility of camphor green oil.—Twenty grams of camphor green oil were weighed in an absorbing vessel with special glass tube. The vessel was connected to a gasometer that was joined to a water pump. Air was pumped into the absorbing vessel and from time to time the amount of the oil was measured. The experiment was carried on for twenty-eight days (at 22° to 28° C.).

TABLE XXXIII.—*Showing volatility of camphor green oil.*

Volume of air. Liters.	Decreased amount of the oil. Per cent.
250	4.11
500	5.37
750	5.90
1,000	6.08

Saturated with 1,000 cubic centimeters of the air, the loss of the green oil was estimated to be 6 per cent of the original volume. It is probable, therefore, that the green oil will remain almost permanently, even when used in the open air.

THE RELATIVE EFFECTIVENESS OF PREVENTIVES

In order to prevent the damage caused by termites, a considerable number of wood preservatives has been invented and some of them are largely used in the Tropics. Although it has been proved that camphor green oil is entirely satisfactory in preventing attack by Formosan termites, it has been thought desirable to determine the effectiveness of other chemicals. For this purpose the following ten preservatives, which are among the commonest in the market, were selected for experiments that were carried on at Tainan, Formosa.

Atlas Preservative A.—This is a mixture of arsenic and sodium hydroxide. Various chemicals containing arsenic are largely used in the Tropics for exterminating termites.

TABLE XXXIV.—*Chemical composition of Atlas Preservative A.*

	Per cent.
Sodium hydroxide	42.20
Arsenic	2.39
Water	55.41

Wood-preservative A.—Manufactured by Nippon Paint and Asphalt Co. Ltd. The principal ingredient of this chemical is tobacco extract. It is made in the following way: Tobacco leaves are boiled in a dilute aqueous solution of hydrochloric acid; the solution is filtrated, and a proper amount of sodium salicylide and a solution of resin soap are added to the filtrate.

Woodilin.—Imported from the United States. This is a mixture of petroleum heavy oil and wood tar.

TABLE XXXV.—*Characteristics of woodilin.*

Color	Dark brown, with fluorescence.	
Specific gravity (at 28°C.)	0.920	
Flashing point (°C.)	51	
Fractional distillation:		Per cent.
110 to 150		0.50
150 to 210		1.50
210 to 240		7.50
240 to 270		10.25
270 to 300		12.75
Above 300		64.00
Residue (weight)		4.88

Woodol.—Manufactured by Ochiai & Co., in Tokyo. The principal ingredient of this preservative is wood tar.

TABLE XXXVI.—*Characteristics of Woodol.*

Color	Dark brown.
Specific gravity (at 28°C.)	1.018
Flashing point (°C.)	52
Fractional distillation:	Per cent.
Below 150	5.50
150 to 200	29.50
200 to 270	8.00
270 to 300	7.99
Above 300	27.00
Residue (weight)	24.38

Carbolin.—Imported from Germany. The principal ingredient of Carbolin seems to be anthracene oil fractionated from coal tar.

TABLE XXXVII.—*Characteristics of Carbolin.*

Color	Dark brown.
Specific gravity (at 28°C.)	1.122
Flashing point (°C.)	123
Fractional distillation:	Per cent.
110 to 210	1.00
210 to 240	6.50
240 to 270	4.00
Above 270	83.00
Residue (weight)	7.50
Crystal of anthracene (weight)	0.20

Avenarius Carbolineum.—Imported from Germany. This is a high fraction of coal tar, mainly containing anthracene oil.

TABLE XXXVIII.—*Characteristics of Avenarius Carbolineum.*

Color	Dark brown.
Specific gravity (at 28°C.)	1.144
Flashing point (°C.)	135
Fractional distillation:	Per cent.
Below 210	1.00
210 to 240	9.80
240 to 270	1.50
Above 270	76.00
Residue (weight)	12.10
Crystal of anthracene (weight)	1.40

Stop-rot.—Imported from England. This wood preservative contains a large quantity of the heavy oil fractionated from coal tar.

TABLE XXXIX.—*Characteristics of Stop-rot.*

Color	Dark brown.	
Specific gravity (at 28°C.)	1.048	
Flashing point (°C.)	85	
Fractional distillation:		Per cent.
Below 210		15.00
210 to 240		17.50
240 to 270		15.00
Above 270		50.50
Residue (weight)		2.00
Naphthalene (weight)		1.40

Carbolineum Atlas.—Imported from Germany; a mixture of the anthracene oil and the heavy oil of petroleum.

TABLE XL.—*Characteristics of Carbolineum Atlas.*

Color	Dark brown.	
Specific gravity (at 28° C.)	1.122	
Flashing point (°C.)	128	
Fractional distillation:		Per cent.
110 to 210		0.50
210 to 240		1.00
240 to 270		8.50
Above 270		62.50
Residue (weight)		26.10
Crystal of anthracene (weight)		0.90

Crepit.—Manufactured by Nippon Wood-preserving Co. Ltd., in Tokyo; mainly consists of creosote oil.

TABLE XLI.—*Characteristics of Crepit.*

Color	Dark brown.	
Specific gravity (at 28° C.)	1.022	
Flashing point (°C.)	115	
Fractional distillation:		Per cent.
Below 210		16.80
210 to 240		33.50
240 to 270		25.00
Above 270		23.30
Residue (weight)		4.50
Crystal of anthracene (weight)		0.30

Wood-preservative B.—Manufactured by Nippon Paint and Asphalt Co. Ltd., in Tokyo. This is a mixture of tobacco extract and creosote oil.

METHOD OF EXPERIMENT

Blocks of cryptomeria (2 by 2 by 15 inches) were coated three times with the preservatives and were buried in ground infested by *Odontotermes formosanus* at Tainan. From time

to time they were dug out for inspection. After eliminating the infested blocks, the remainder were buried again. This experiment was carried on for three years, starting on June 24, 1910 (Plate XI, fig. 1). Dates of inspection: July 4, 1911; July 14, 1912; July 14, 1913.

TABLE XLII.—*Result of the experiment.*

Date of inspection.	Preservative.	Number.	Blocks.			Damage.	Dry rot.
			Infested.	Dry rot.	No damage.		
						P. ct.	*P. ct.*
July 4, 1911	Wood-preservative A	5	5	0	0	100.0	0
July 14, 1912	Atlas Preservative A	7	5	2	0	71.4	28.6
July 14, 1913	Woodilin	4	3	1	0	75.0	25.0
Do	Woodol	3	3	0	0	100.0	0
Do	Carbolin	5	0	0	5	0	0
Do	Avenarius Carbolineum	3	1	0	2	33.3	0
Do	Stop-rot	3	2	0	1	66.7	0
Do	Carbolineum Atlas	4	2	0	2	50.0	0
Do	Crepit	4	3	1	0	75.0	25.0
Do	Wood-preservative B	3	3	0	0	100.0	0

As shown in Table XLII, none of the chemicals except Carbolin, Avenarius Carbolineum, Stop-rot, and Carbolineum Atlas is effective in preventing the attack of *Odontotermes formosanus* and fungi as well. It is rather striking that the above-named four chemicals, which are more or less effective, are the high fraction of coal tar, mainly consisting of anthracene oil distilled at a temperature above 270° C. Moreover, the percentage of damage is inversely proportional to the amount of the anthracene oil.

TABLE XLIII.—*Relative values of preventives and the percentage of anthracene oil in each.*

Preventive.	Damage.	Anthracene oil.
	Per cent.	*Per cent.*
Stop-rot	66.7	50.5
Carbolineum Atlas	50.0	62.5
Avenarius Carbolineum	33.3	76.0
Carbolin	0.0	83.0

It is evident, therefore, that the anthracene oil is a factor in determining the effectiveness of those chemicals.

Anthracene oil, being a product of destructive distillation of coal tar, emits a characteristic, unpleasant odor. At the same time it is dirty and viscous. Of course, there is no objection to the use of this oil in the field; that is, for the sake of preservation of railway sleepers or electric poles. However, it is not recommended for use in houses, on account of its staining timbers.

SUMMARY

1. In Formosa three species of termite, namely, *Leucotermes flaviceps* Oshima, *Coptotermes formosanus* Shiraki, and *Odontotermes formosanus* (Shiraki), are injurious to wooden structures.
2. A pair of mature individuals of *Coptotermes formosanus* is able to start a new colony.
3. In a newly stablished colony of *Coptotermes formosanus*, egg laying begins five to thirteen days after swarming.
4. *Coptotermes formosanus* lays from one to four eggs a day.
5. Eggs of *Coptotermes formosanus* hatch in from twenty-four to thirty-two days after they are laid.
6. The soldier of *Coptotermes formosanus* develops from the egg laid by the queen.
7. *Coptotermes formosanus* attacks lime mortar.
8. The principal food of *Coptotermes formosanus* is cellulose.
9. The termite-proof concrete layer is entirely satisfactory in preventing the entrance of termites from the ground.
10. Teak and cypress pine are absolutely immune from the attack of Formosan termites.
11. The resistance of timber is not due to its hardness or weight.
12. The resistance of timber is not due to the inorganic compounds contained in it.
13. The resistance of timber is due to organic compounds that can be extracted by benzene or alcohol.
14. Cypress pine contains "guajol," a sesquiterpene alcohol.
15. Foochow cedar and Randai cedar contain "cedrol," a sesquiterpene alcohol.
16. The resistance of timber is due to the presence of sesquiterpene alcohol.
17. Camphor green oil contains 25 per cent of sesquiterpene alcohol.
18. Camphor green oil is entirely satisfactory as a preventive for buildings.
19. The anthracene oil fractionated from coal tar is effective in preventing the damage of *Odontotermes formosanus*.

ILLUSTRATIONS

PLATE I

FIG. 1. *Coptotermes formosanus*, soldier.
2. *Coptotermes formosanus*, forewing.
3. *Coptotermes formosanus*, hind wing.
4. *Odontotermes formosanus*, soldier.
5. *Odontotermes formosanus*, forewing.
6. *Odontotermes, formosanus*, hind wing.

PLATE II

FIG. 1. A nest of *Coptotermes formosanus*, in its natural position. Found at Kokura, Japan.
2. A nest of *Coptotermes formosanus*, constructed at the top of a king-post. Found in Taihoku, Formosa.

PLATE III

FIG. 1. The covered tunnel constructed by *Coptotermes formosanus*.
2. A cross section of a nest of *Coptotermes formosanus*. *a*, the royal chamber for the queen; *b*, the royal chamber for the king.

PLATE IV

FIG. 1. One end of a common rafter, showing the method of attack by termites. The year rings remain, while the soft parts are entirely eaten up.
2. Part of a tiebeam, damaged by termites; from a residence in Taihoku.
3. One end of a pillar, damaged by termites; from the porch of the Civil Governor's residence in Taihoku.

PLATE V

FIG. 1. Damage to wooden stairway, in a military storehouse in Kiushiu, Japan.
2. Damage to foundation timbers of a Japanese building.
3. A seriously damaged tiebeam, in a military storehouse in Kiushiu, Japan.

PLATE VI

FIG. 1. The pathway of *Coptotermes formosanus* through a wall. The main entrance of the Civil Governor's residence in Taihoku; one part of the walls was removed in order to trace the passage.
2. The residence of the Chief of the Communication Bureau, Government of Formosa, seriously attacked by *Coptotermes formosanus*.

PLATE VII

FIG. 1. A piece of infested brick wall, showing the passage of *Coptotermes formosanus* through lime mortar (horizontal surface of the bricks). White crosses indicate the dissolved passage.

2. A piece of lime mortar which was evidently perforated by *Coptotermes formosanus*.
3. Lateral view of one part of an infested brick wall, showing the void which contains several termites, *Coptotermes formosanus*.

PLATE VIII

FIG. 1. Cross section of a rail fixed to a sleeper, showing the basal surface of the latter broken by the tip of the spike.

2. Cross sections of infested sleepers, passing through the position of the spike.
3. Railway sleepers, of untreated chestnut, upper surface infested by *Odontotermes formosanus*. The positions of the rails are indicated at the middle. Found in the main line near Tainan, Formosa.

PLATE IX

FIG. 1. Scene of the construction of a termite-proof concrete layer over the whole surface of a building site.

2. A model of the termite-proof building construction in Formosa, showing the concrete layer on the ground level.

PLATE X

FIG. 1. Nippon Yusen Kaisha (N. Y. K. Steamship Co.) termite-proof brick building, at Keelung, Formosa.

2. One part of the second floor of the N. Y. K. building shown in fig. 1, showing the damage caused by *Coptotermes formosanus*.

PLATE XI

FIG. 1. The experiment station at Tainan, Formosa. Blocks are dug out.

2. Blocks used in an experiment: *a*, control, untreated pine, after one week; *b*, a block of pine, treated with cypress pine oil, after one year; *c*, a block of pine, treated with camphor green oil, after one year.

PLATE XII

Examples of termite-proof, brick building construction.

PLATE XIII

FIG. 1. Brick building, showing the method of termite-proof building construction adopted until the year 1916.

2. Brick building, showing a new method adopted since the year 1916.
3. Details of fig. 2, showing the construction of the second floor.
4. Wood construction.
5. Details of fig. 4.

TEXT FIGURES

FIG. 1. Test tube for rearing termites: *a*, absorbent cotton; *a'*, food; *b*, clay; *c*, cork.

2. Detail of termite-proof construction; a continuous layer of cement at ground level.

3. Detail of termite-proof construction; a layer of cement at ground level laid in two parts.

4. Detail of termite-proof construction; a layer of cement at ground level laid in three parts.

5. Detail of termite-proof construction; the protective layer at two levels.

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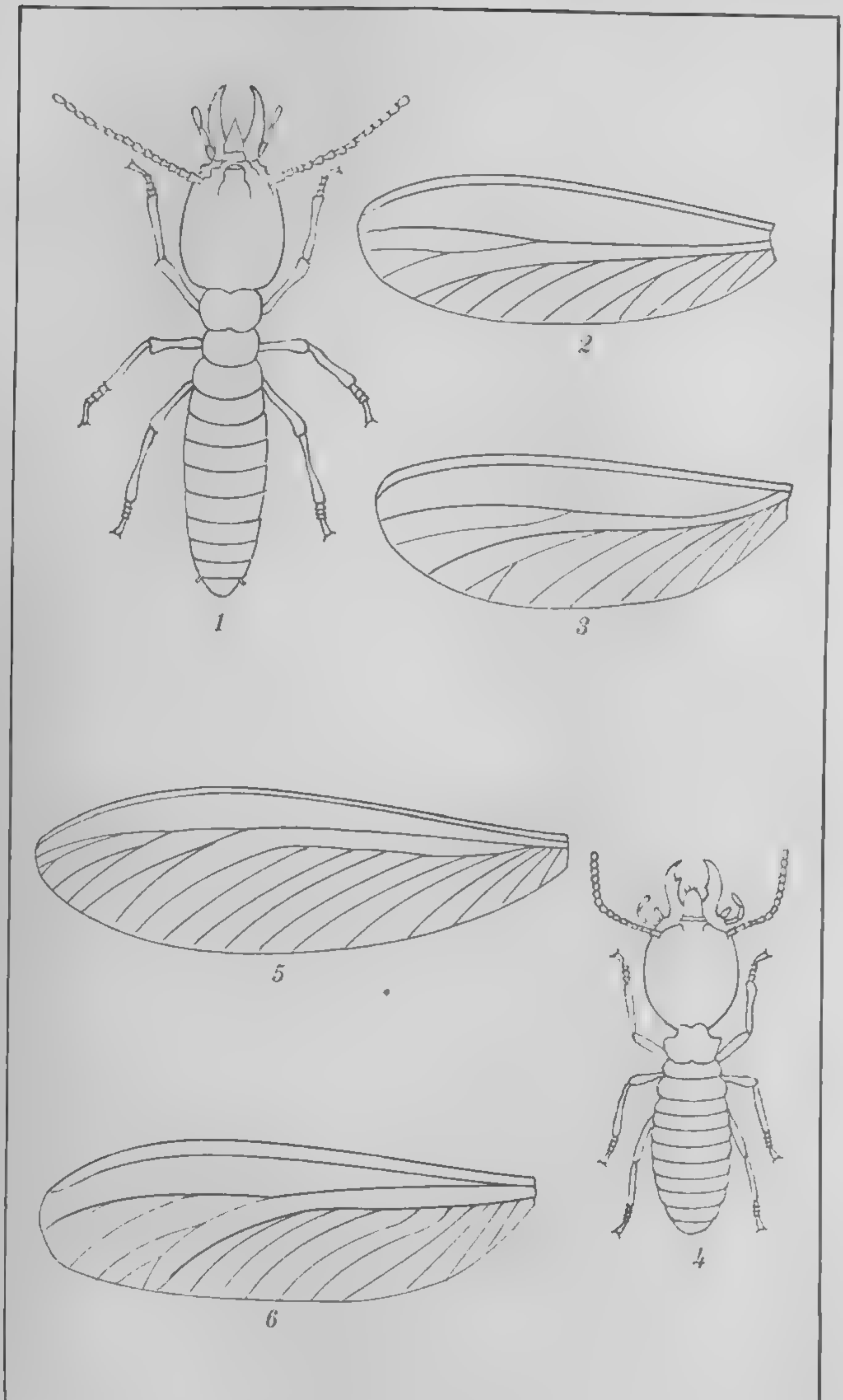

PLATE 1. SOLDIERS AND WINGS OF TERMITES.

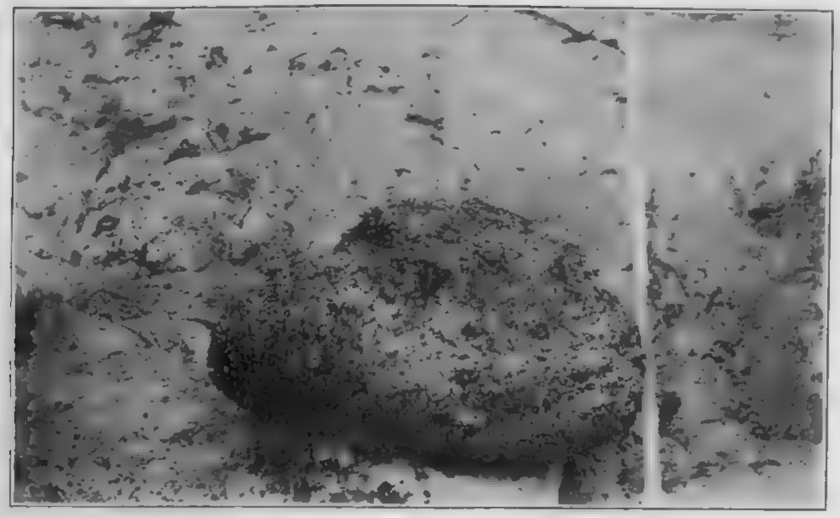

Fig. 1. A termites' nest in its natural position.

Fig. 2. A termites' nest at the top of a king-post.

PLATE II.

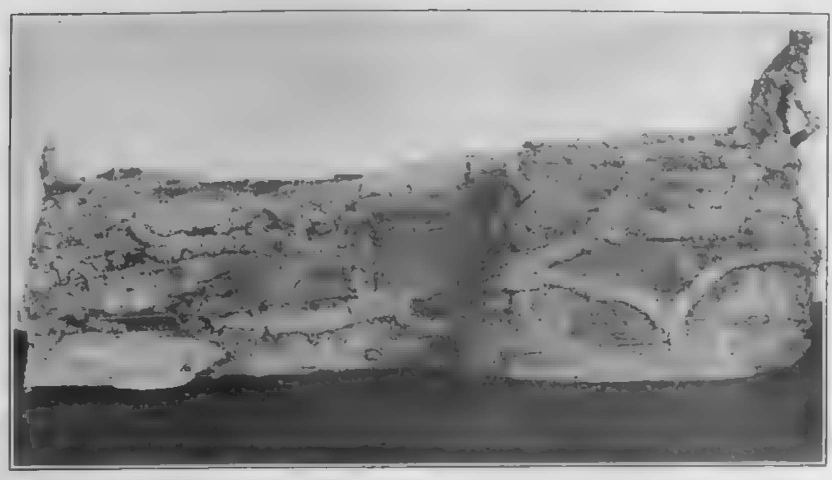

Fig. 1. The covered tunnel built by termites.

Fig. 2. Cross section of a termites' nest; *a* and *b*, royal chambers.

PLATE III.

Fig. 1. One end of a rafter.

Fig. 2. Part of a tiebeam.

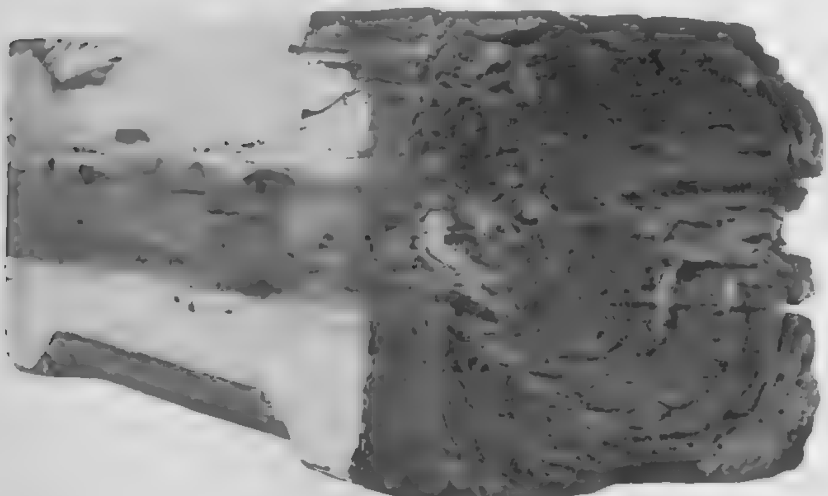

Fig. 3. One end of a pillar.

PLATE IV. DAMAGE DONE BY TERMITES.

PLATE V. DAMAGE DONE BY TERMITES.

Fig. 1. Pathway of termites in a wall.

Fig. 2. Exterior of a damaged building.

PLATE VI.

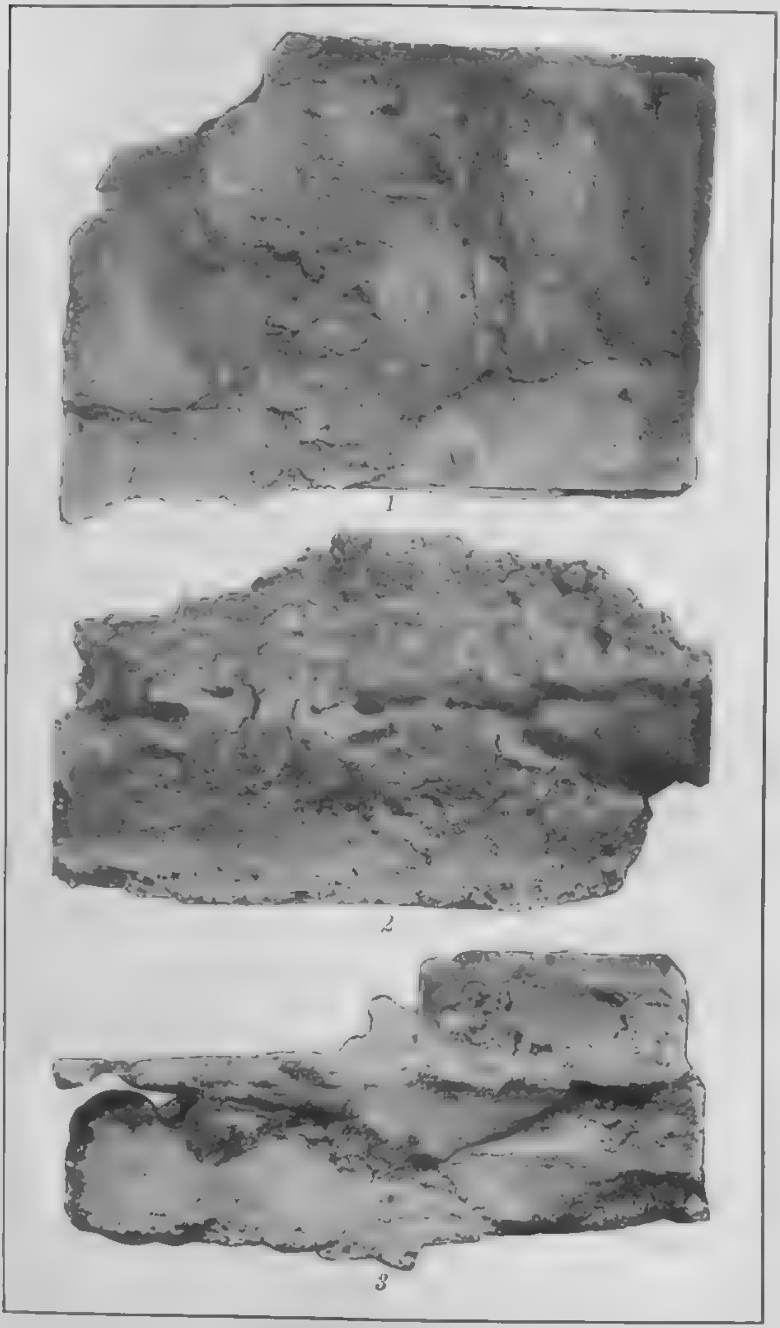

PLATE VII. TERMITES IN BRICK WALLS.

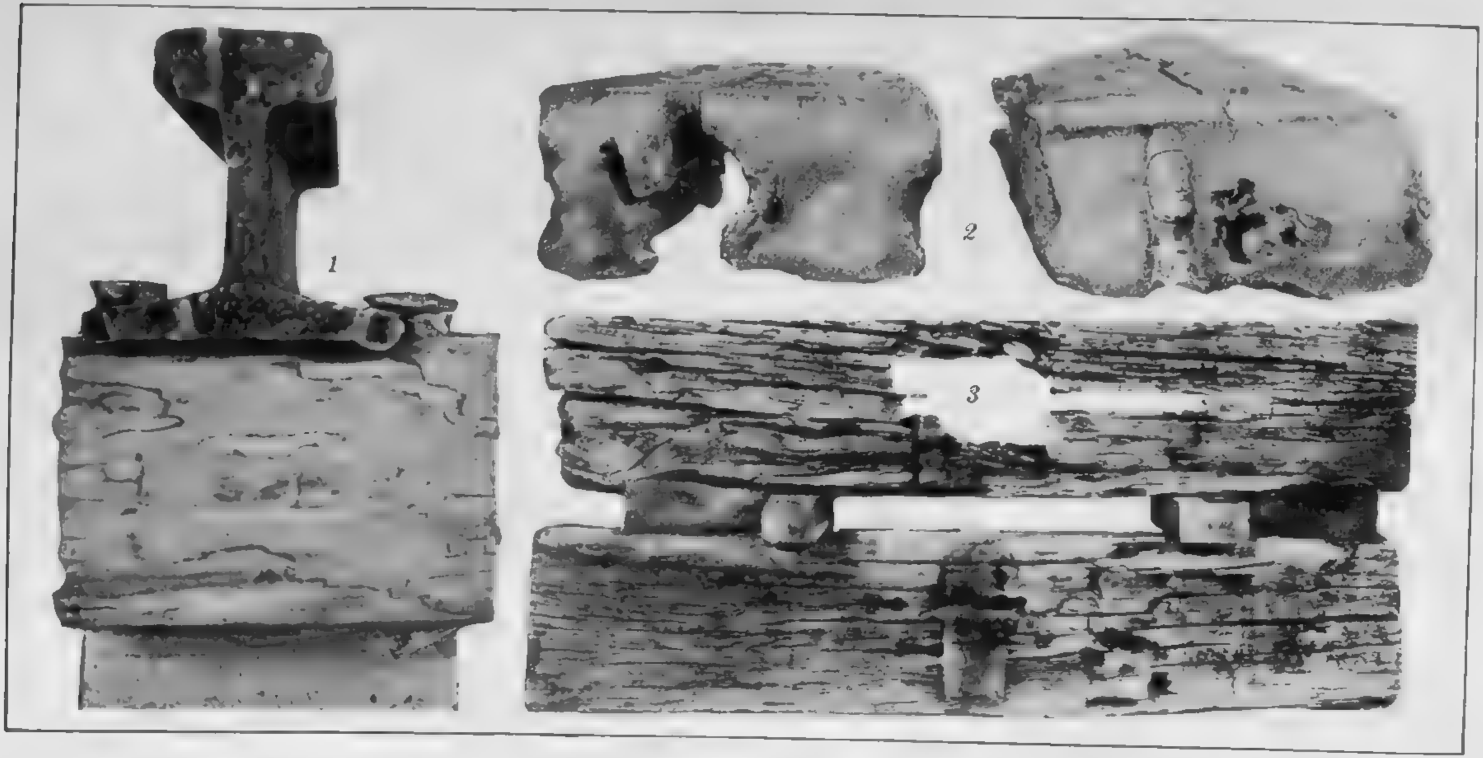

PLATE VIII. RAILWAY SLEEPERS DAMAGED BY TERMITES.

Fig. 1. Construction of a termite-proof concrete layer.

Fig. 2. Model of a termite-proof building.

PLATE IX.

Fig. 1. A termite-proof brick building.

PLATE X.

Fig. 2. Damage to woodwork on second floor of the building shown in fig. 1.

Fig. 1. The experiment station at Tainan, Formosa.

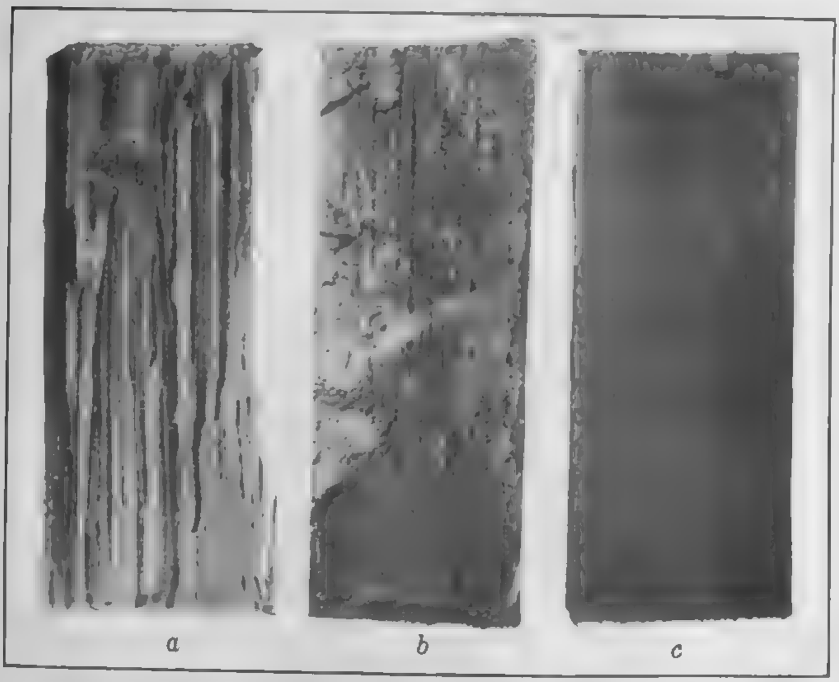

Fig. 2. Test blocks of pine.

PLATE XI.

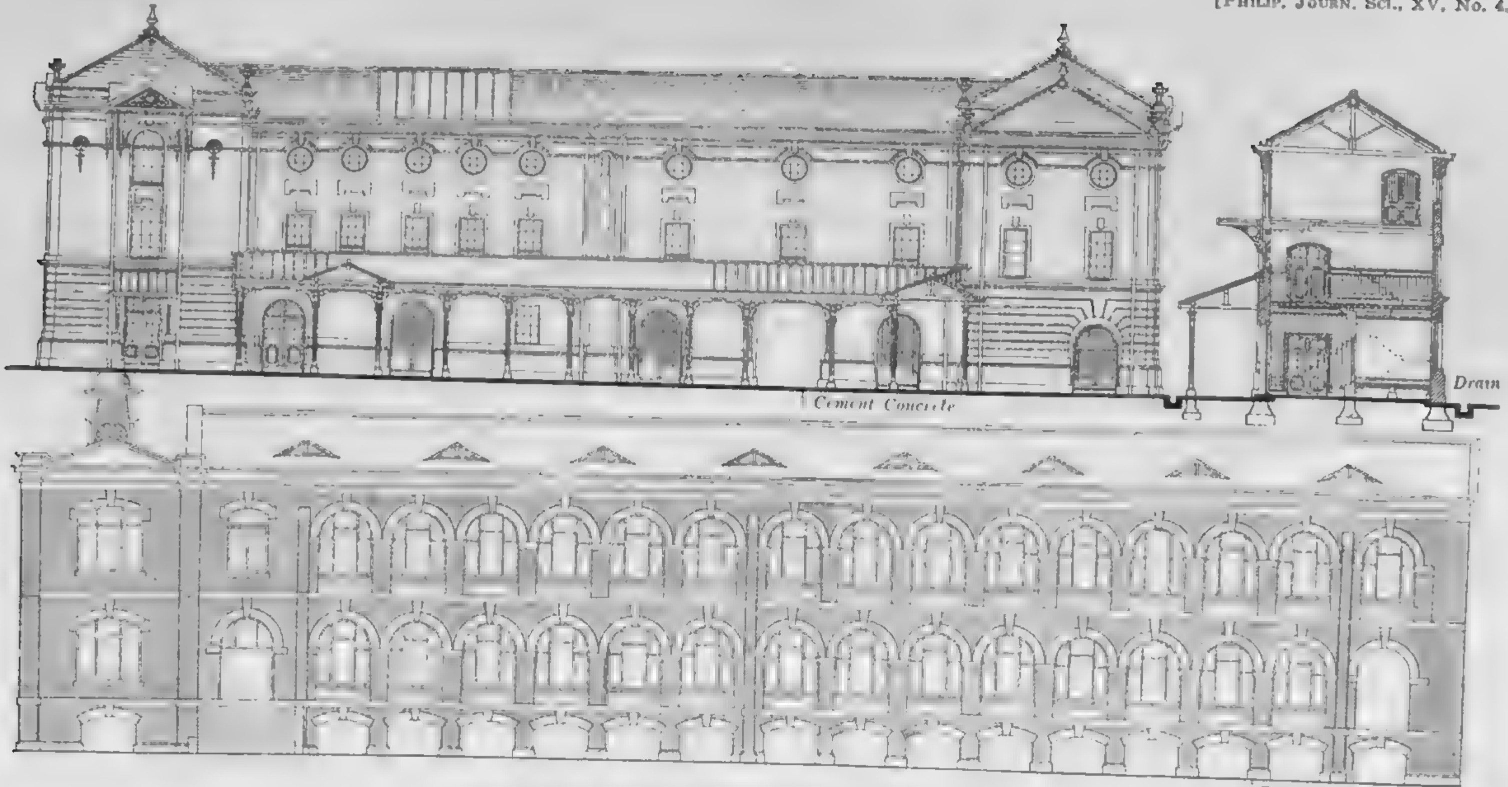

PLATE XII. EXAMPLES OF TERMITE-PROOF BRICK BUILDINGS.

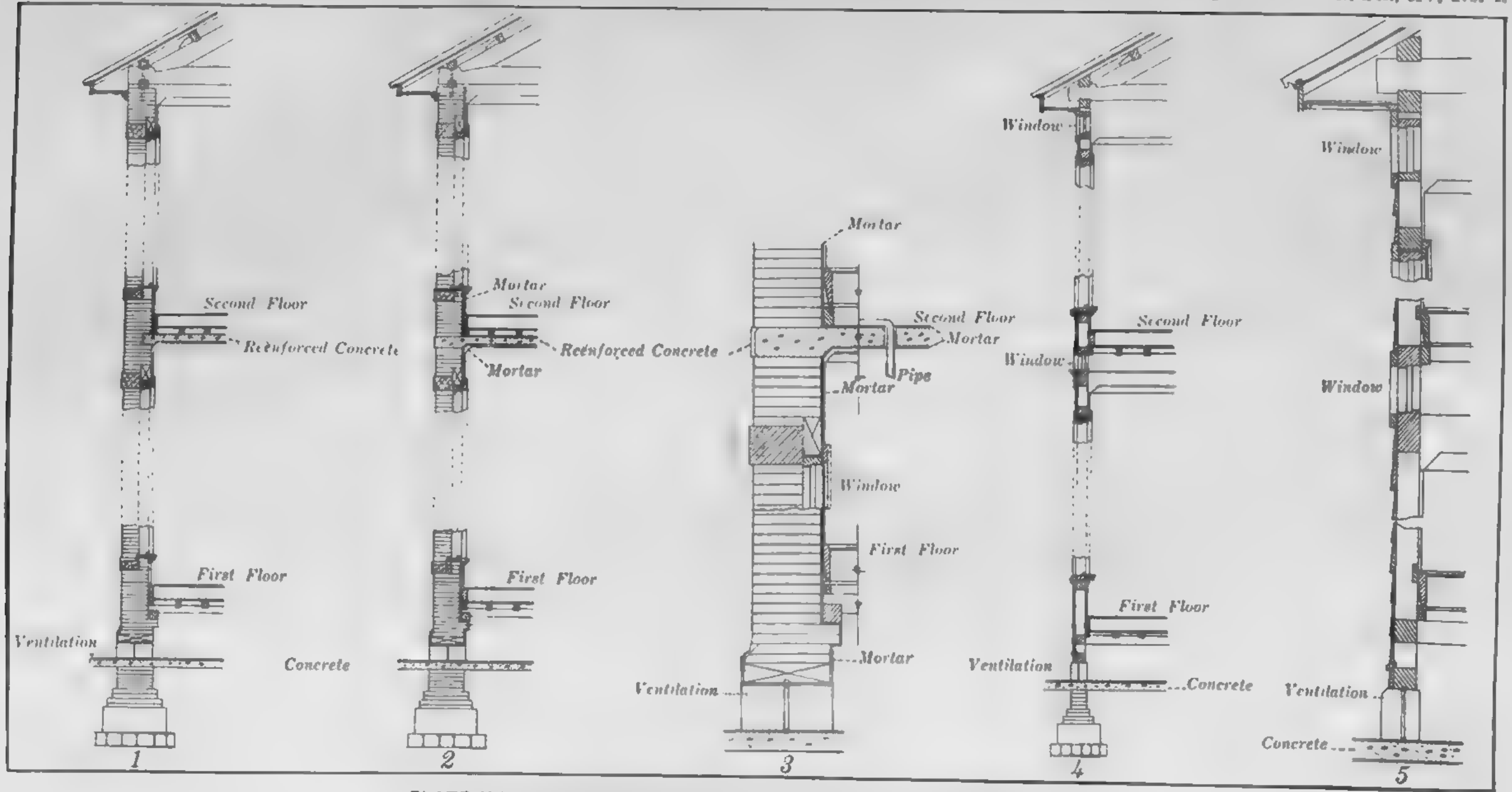

PLATE XIII. EXAMPLES OF TERMITE-PROOF BUILDING CONSTRUCTION.

A NEW SCALE INSECT ON RHIZOPHORA

By T. D. A. Cockerell

Of the University of Colorado

ONE TEXT FIGURE

The mangroves (*Rhizophora*), fringing tropical shores, have been found to support a peculiar coccid fauna, including *Ctenochiton rhizophoræ* Maskell in Australia, *Mesolecanium rhizophoræ* Cockerell in Brazil, and *Chrysomphalus rhizophoræ* Cockerell in Mexico. A new species is now to be described from the Philippine Islands.

Targionia merrilli sp. nov. Text fig. 1.

Female scale 3 to 3.5 millimeters in diameter, flattened, somewhat convex, circular, pale gray; first skin near margin, appearing as a small black nipplelike prominence. Young scales reddish, with the first skin orange.

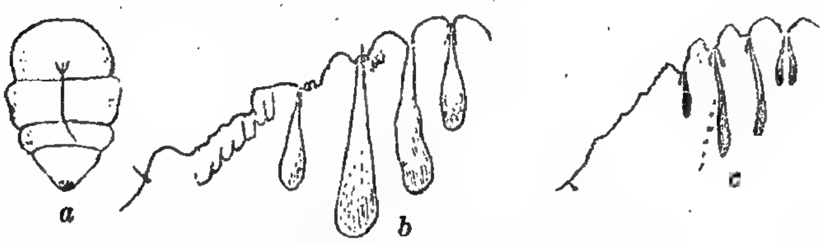

FIG. 1. *Targionia merrilli* sp. nov., *a*, female insect; *b*, caudal end of female; *c*, *Chrysomphalus rhizophoræ* Cockerell, caudal end of female.

Female dark brown, about 2.5 millimeters long; cephalic region broadly rounded, separated by a deep suture from the wider thoracic region; no circumgenital glands; anal orifice narrow and elongate, about 100 μ from hind end; five pairs of low lobes, the first broad and close together, but not touching; second and third broad and rounded, the third sometimes distinctly notched; fourth very broad, with the margin variable, but usually more or less flattened or tablelike in outline; fifth rounded, widely separated from fourth; spines small and inconspicuous; squames very minute, rudimentary; at the bases of the lobes are long claviform paraphyses or glands, one be-

tween median lobes; one, nearly twice as long, between first and second lobes; a similar one just mesad of third lobe; and a smaller one mesad of fourth lobe.

On upper and under sides of leaves of *Rhizophora mucronata* Lamarck, Manila, Philippine Islands, September, 1918 (*E. D. Merrill*).

This is a very distinct species, somewhat related to *Targionia mooeri* (Green), from India, but easily recognized by the numerous lobes and large claviform thickenings or glands, which recall those of *Chrysomphalus quadriclavatus* (Green), found on *Murraya exotica* in Ceylon. Green calls these structures clubbed paraphyses. It is rather remarkable that the Mexican *Chrysomphalus rhizophoræ,* which has groups of circumgenital glands and is not closely related to *Targionia merrilli,* also has very long paraphyses. I give a sketch of the caudal end of this insect (not before figured) for comparison.

ILLUSTRATION

TEXT FIGURE

FIG. 1. *Targionia merrilli* sp. nov., *a*, female insect; *b*, caudal end of female; *c*, *Chrysomphalus rhizophoræ* Cockerell, caudal end of female.

BALANTIDIUM HAUGHWOUTI, NEW SPECIES, PARASITIC IN THE INTESTINAL TRACT OF AMPULLARIA SPECIES, A MORPHOLOGICAL STUDY

WITH REMARKS ON THE RELATION BETWEEN THE MEGANUCLEUS AND THE MICRONUCLEUS [1]

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ONE PLATE AND FIVE TEXT FIGURES

INTRODUCTION

This is a study of the structures and the characters of what appears to be a new species of *Balantidium* found parasitic in the intestinal tract of a fresh-water snail, *Ampullaria* sp. The parasites were first seen by Prof. Frank G. Haughwout in the original host found in the pond on the ground of the Bureau of Science, Manila.

The host, *Ampullaria*, is a very common inhabitant of fresh waters in the Philippine Islands. It thrives luxuriantly about the banks and the bottoms of shallow rivers and ponds. It is known in the vernacular as "cohol" and is much used as a food by the Filipinos.

The discovery of this species is of some systematic interest in that it forms an addition to the species of *Balantidium* that have been found infesting invertebrate hosts.

THE GENUS BALANTIDIUM

The genus *Balantidium* was founded by Claparede and Lachman.(10) It consists of heterotrichous ciliates, free-swimming or histozoic, oval in shape, slightly truncated anteriorly and more rounded posteriorly. A small triangular excavation, anteriorly, forms the peristome at the bottom of which opens the cytostome which leads backward into a fairly well-developed

[1] From the department of parasitology. Submitted in partial fulfillment of the requirements for the degree of Doctor of Tropical Medicine, Graduate School of Tropical Medicine and Public Health, College of Medicine and Surgery, University of the Philippines.

or rudimentary cytopharynx. The peristome area bears an adoral zone of membranelles which are continuous with a line of slender, delicate cilia or membranelles which line the gullet. An anal aperture or cytopyge is usually present at the most posterior point of the body. Contractile vacuoles are present in varying numbers. The meganucleus is oval, bean-shaped, or reniform. The organisms occur as entozoic parasites of vertebrates and invertebrates.

Systematically the genus *Balantidium* falls in the subphylum Infusoria; class Ciliata; order Heterotrichida; suborder Polytrichina; and family Bursaridæ. In this genus are included the following species:

Balantidium entozoön Ehrenberg.

Found as an obligate parasite in the rectum of the common frogs *Rana temporaria* and *R. esculenta*. It was first described by Leeuwenhoek in 1722. It has an oval or pyriform body. narrowed anteriorly. This narrow anterior end is somewhat curved to one side and obliquely truncate. It is provided with a peristome area which extends backward and continues into a well-defined gullet. There are four contractile vacuoles. The meganucleus is sausage-shaped. It measures 105 μ to 635 μ.

Balantidium elongatum Stein.

Found as a parasite in the intestinal canal of *Triton tæniatus* and *Rana esculenta*. It has a length of 212 μ to 302 μ which is two to two and one-half times its breadth. The body is "elongate-fusiform, subcylindrical," tapering anteriorly. The peristome area is slitlike, short, and lies in a medium position without any distinct cytopharynx. There are usually two distinct vacuoles. The meganucleus is oval in shape.

Balantidium coli Malmsten.

This species was discovered in the bowel discharges of two patients suffering from chronic diarrhœa. The organism was described by Malmsten under the designation *Paramecium coli*. Stein later discovered the same species in the intestinal tract of hogs. The body is oval, the anterior end being either broader or more pointed, according to the degree of contraction of the peristome area. It measures 60 μ to 100 μ in length and 50 μ to 70 μ in width. The peristome is triangular or funnel-shaped. The pharynx is not very distinct. There are two contractile vacuoles. There is a cytopyge that is postero-terminal. The meganucleus is bean-shaped or reniform. The micronucleus is

small and spherical. This is the only species so far proved to be pathogenic to its host.

Balantidium duodeni Stein.

This species has been found in the duodenum of the edible frog *Rana esculenta.* It differs from *Balantidium entozoön,* a parasite of the same host, in that the cuticular cilia of *B. duodeni* are longer and finer and are "mostly directed forwards and have a tendency to group themselves into even, longitudinally disposed, pencil-like tufts." It has a length of 85 μ to 132 μ, barely exceeding its breadth. It has a short, oval, flattened body with a short, narrow, slitlike peristome. There is no distinct cytopharynx. The meganucleus is oval. There is only one contractile vacuole, and this lies at one side of the body posteriorly.

Balantidium medusarum Mereschowsky.

Parasitic in the alimentary and radial canals of the medusæ of the coelenterate forms *Eucope* and *Bougainvillea.* Brada, as quoted by Saville-Kent (9) has also reported it as occurring in certain marine worms. The body is soft, flexible, and somewhat oval; it measures 42 μ in length, this being about twice the width of the body. The peristome is prolonged backward and is supplied on the left border with an even row of powerful adoral membranelles. The surface of the body is distinctly marked with numerous longitudinal striæ that are interlaced by finer, less conspicuous transverse striations. The body is supplied with long, slender, fine cilia that are well scattered. There are one or two contractile vacuoles. The meganucleus is slightly oval and may be rounded; it is usually central in position.

Balantidium minutum Schaudinn.

This is a parasite of the human intestinal tract, its local habitat being the small intestine, particularly the duodenum. It appears only in the stools during active diarrhœa. The body is oval, pointed anteriorly and more rounded at the posterior end. It ranges in length from 20 μ to 32 μ with a width of from 14 μ to 20 μ. The peristome is fissurelike and ends at the center of the body. The right lateral border of this peristome is supplied with a row of cilia of the same size as those appearing on the general surface of the body. The left side expands laterally into a "thin hyaline membrane that extends towards the back and can pass over to the right side." There is a single contractile vacuole situated posterodorsally. The meganucleus is

rounded in shape, centrally placed, and measures 6 μ to 7 μ in diameter. The micronucleus, which lies in its vicinity, is also rounded and measures only 1 μ in diameter. The cysts are oval.

Balantidium falcifarum Walker. (12)

Found in the large intestine of the frog *Rana palustris* Leconte. The body is falciform and oval in cross section. The anterior end of the body is narrow and truncated obliquely to the right. The peristome is limited to the anterior end. The cytopharynx is very short. The meganucleus, lying either in the middle of the body or a little posteriorly, has an oval or rounded shape. It measures 3.8 μ to 4.6 μ in diameter. The size of the organism is from 30 μ to 35 μ by 10 μ to 15 μ. According to Walker it sporulates on artificial media. The cysts are round and single-walled and their contents granular.

Balantidium orchestis Watson (Kamm). (13)

Parasitic in the alimentary tract of *Orchestia agilis* and *Talorchestia longicornis*. The body of this species is ovoidal or ellipsoidal and measures from 300 μ to 360 μ in length with a width of from 180 μ to 220 μ. The meganucleus is ellipsoidal. The micronucleus, which is small, lies close to the meganucleus. The peristome is small and inconspicuous and leads into a short, slender œsophagus. There is a single contractile vacuole at the posterior end.

Balantidium coli var. hondurense Barlow.

This is described by Barlow as differing from *Balantidium coli* in that the cilia are not arranged in rows; there is no contractile vacuole; and the cytopyge, or anus, is contractile. The micronucleus, Barlow says, is difficult to demonstrate. This is an interesting form that requires further study.

Balantidium italicum Sangiorgi and Ugdulena. (8)

This is described by Sangiorgi and Ugdulena as very similar to *Balantidium minutum* Schaudinn, the only differences being the eccentric position of its nuclear apparatus and the inconstant relative position of the micronucleus with regard to the meganucleus. This organism has been found in human diarrhœic stools. It has been successfully cultivated in peptone water and agar-agar media. The average size of those grown in peptone water is 31.5 μ by 14 μ and those grown in agar, 33 μ by 25 μ.

Fantham, Stevens, and Theobald (3) mention species of *Balantidium* occurring in polychæte annelids, and various authors have described balantidia from the human intestinal tract to which

they have given new specific names. In the latter case the question arises as to the validity of these species, and further work on them is clearly indicated.

MATERIAL AND METHODS

In studying the parasite to be described the snail host was dissected, the intestinal tract isolated and where whole mounts were needed the intestinal contents were teased out, smeared directly over the slides, and immediately fixed. Intestines were sectioned at different levels to detect the site of parasitism as well as to throw light on the matter of tissue invasion. Sections of individual balantidia were also prepared for the study of the minute cytoplasmic and nuclear structures. In every case fixation was carried out either in sublimate-acetic fluid [2] or in Bouin's picro-aceto-formol solution. Sections were stained either by Heidenhain's iron-hæmatoxylin or by the iron-hæmatein method of Dobell.(2) Total mounts were stained with Delafield's hæmatoxylin or with the picro-carmine of Hoyer.

The living organisms were studied in the intestinal fluid of the host or in physiological salt solution.

The animals to be measured were killed in Worcester's fluid [3] and measured directly by the ocular micrometer at a magnification of 1,280 diameters. Both large and small individuals were taken at random as they occurred on the slide.

The proportion of infected snails was found to be about 95 per cent, after the animals had been kept in the laboratory aquarium for a few days; but if examined immediately after they were taken from the pond, fully 99 per cent of well-fed snails containing an abundance of food in the gut were found to be parasitized. As the snails are kept longer in the laboratory and the intestinal contents diminish as a result of the lessening food supply the heaviness of the infection is correspondingly lowered. Under such conditions of partial starvation the parasites look lean, flat, transparent, and granular, instead of robust and alveolar. If they are kept a few weeks longer in the laboratory, examination of all the snails will prove negative.

Under these conditions the parasites apparently leave their host, either being discharged with the intestinal contents or swimming out by themselves to assume the exogenous phase in

[2] Saturated solution of mercuric chloride in sea water, 95 parts; glacial acetic acid, 5 parts.

[3] Saturated solution of mercuric chloride in 10 per cent formol, 9 parts; glacial acetic acid, 1 part.

their life cycle. As the snails are kept longer in the aquarium the balantidia apparently increase in numbers in the water of the aquarium. Whether or not they divide under these circumstances cannot be said. Outside of the snail, however, they seem to have but a short period of existence, as free-living forms, since they disappear in four or five days. Whether they encyst at this period or succumb to the toxic substances produced by the overgrowth of bacteria and spirilla is yet to be determined. So far, the cysts have not been determined with certainty.

SITE OF PARASITISM

Smear preparations of entire organisms and sections 5 μ thick cut from different portions of the gut show that the parts most infested are the mid- and the hind-guts, especially those parts usually rich in intestinal contents from which the animal mainly derives its food.

In these sections the organisms were always found confined to the lumen of the gut, lying in the intestinal content. I never have observed an instance where tissue had been invaded or, indeed, any evidence that might be interpreted as an attempt to penetrate the intestinal wall.

MORPHOLOGY

In fresh preparations the organism has the appearance of a miniature balloon, slightly flattened dorsoventrally, tapering evenly and gradually to a blunt anterior end and expanding into a posterior rounded extremity where, often, a very minute conical papilla can be seen. At this spot is located a minute anal opening, the cytopyge, attached to which, in an actively feeding animal, can be observed a stalk that looks like a mucoid thread. In one instance I observed an individual attached to a fragment of intestinal tissue by means of this "stalk." The structure, in a way, recalls the attaching organ of the free-living hypotrichous ciliate *Ancystropodium maupasi* as described by Faure-Fremiet.(4) The anal papilla somewhat resembles apparently similar structures figured by Stein in connection with his descriptions of *Balantidium coli* and *B. duodeni*.

Viewed from the sides the dorsoventral flattening of the body is very apparent. Ventrally, at about the junction of the anterior and middle thirds of the body and just at the site of the ventral lip, the median portion is depressed, forming an inpocketing that constitutes the triangular excavation at the bottom of which lies the opening of the cytostome. Under normal

conditions, the animal maintains a constant body form and externally is bilaterally symmetrical. When disturbed, however, as when it is placed in a foreign medium, the animal can assume a slipperlike form with marked flattening. This may at times give an appearance superficially resembling that of *Paramoecium caudatum.* This illustrates the marked plasticity of the organism. When placed under restraint, as by pressing the cover glass down against the slide, or when the animals are compelled to swim through tangled strands of cotton, this plasticity enables them to assume shapes so varied that when seen for the first time under such conditions they might almost be mistaken for amœbæ. This is a phenomenon of frequent occurrence among the Ciliata.

Placed in their natural medium, that is to say, the intestinal juice of the host snail, these organisms can be seen to progress evenly and gracefully with a slight rotary motion. When slightly disturbed or placed in a foreign medium they move rapidly by a series of jerks and dashes and sudden turns, coupled with vigorous rotation about the long axis. When put under pressure or placed under some obstruction the animals take on the "amœboid" movement before mentioned, the elasticity and the flexibility of the cell wall being well shown under these conditions. This movement, however, is not amœboid movement in the true sense.

Furthermore, the anterior end of the animal seems capable of protrusion to a considerable extent, and it is likewise capable of flexion in every direction. In this respect the anterior end of the animal really behaves very much as does the pseudopodium of a rhizopod, apparently serving to guide the animal in forward progression among obstacles. The rest of the body follows by successive regional contractions and adaptations of the cell wall accompanied by rapid cyclosis of the endoplasm in the direction of the anterior end. The coarsely granular protoplasm, the nuclei, and the vacuoles follow the anteriorly situated finely granular endoplasm.

This species is one of the smaller of those included in the genus *Balantidium.* Its average length, computed from a series of fifty individuals selected at random, was 50 μ; the average width was 40 μ. The animal is widest at the posterior third of the body, the anterior third being the narrowest portion.

CYTOLOGY

The organism is clothed with a fairly thick cuticle—homogenous, transparent, and refractive. Under ordinary conditions this cuticle appears to be firm enough to keep the shape of the animal constant, and yet under certain circumstances it is seen to be flexible enough to allow considerable movement and change of shape. The cuticle is traversed by longitudinal lines or striations, which on the dorsal surface run from pole to pole; on the ventral surface, anteriorly, they curve dorsad and converge, following the depression that marks the position of the adoral zone. From these lines spring the comparatively long, slender, and delicate cilia, the coördinated fibrillary movements of which propel the animal forward. I have been unable to demonstrate basal granules at the origin of the cilia. It is not certain that these longitudinal lines actually are ridges because in cross sections of the organisms the cuticle does not show any raised or differentiated areas. It is probable that the lines represent the insertion of myonemes, the contractions of which bring about the movements of the body. The seeming absence of basal granules might be explained on the basis of the supposition that kinetic elements, common to both the myonemes and the cilia, are contained within the myonemes.

These lines are plainly visible in the living organism, but are hard to distinguish in the fixed and stained specimens. While the contractile mechanism of this species is somewhat similar to that seen in the closely related genera *Stentor* and *Spirostemum*, the body does not show the high degree of contractility exhibited by those two nonparasitic forms.

The medulla consists of two distinct cytoplasmic zones; namely a finely granular ectoplasm, and a coarsely granular endoplasm.

The ectoplasm consists of a narrow strip of clear, almost homogenous, refractive, and finely granular cytoplasm around the periphery of the cell which, just above the terminus of the cytopharynx and at the level of the oral depression, apparently expands and becomes continuous with an area of similar structure occupying the anterior third of the organism. This is probably an optical effect due to the thinness of the body at this point and where the endoplasm would appear to be relatively scant in quantity.

This anterior third of the animal is a blunted cone which is excavated ventrally. Its base is represented by a line of demarcation sharply seen (see fig. 2, *b* and *c*), especially in the

fresh specimen, at its junction with the middle third convex superiorly, dividing abruptly, the finer granular and the coarsely granular cytoplasm lying posterior to it. This constitutes the upper limit of the latter. At the extremities of this line may be observed, in favorable individuals, a slight constriction or indentation of the cell wall forming some sort of a neck to the individual, a fact which shows that the posterior portion is more elastic and expansible laterally than the anterior which, as has been previously noted, is capable of comparatively wide extension along the longitudinal axis. Moreover, this line corresponds, on the ventral surface, to the edge or ventral lip of the oral excavation.

Dorsally, at the most anterior part of this conical structure, a row of membranelles is seen constantly in motion. This dorsal portion constitutes the dorsal lip of the adoral excavation. It is continued laterally on both sides as a thin expansion forming the lateral wall through which, under deeper focus, can be seen the structure of the oral apparatus. Ventrally, the median anterior surface does not reach the most anterior part of the animal. Instead it makes an acute dorsoposterior fold to form the adoral excavation already mentioned.

The excavation itself is funnel-shaped. At the bottom of it lies the cytostome which leads into a small canal, the cytopharynx, which, in turn, runs a short course dorsoposteriorly to end blindly in the endoplasm in the vicinity of the meganucleus. The opening between the dorsal and ventral lips measures about 11.5 μ. The adoral zone is well supplied with membranelles. The cytopharynx is ciliated. The united action of these membranelles and cilia, the movements of which are coördinated, serves to conduct the current of food to the endoplasm. The dorsal lip of the adoral excavation is probably supplied with myonemes, since the oral area can be much expanded during active feeding.

The posterior two-thirds part of the animal is darker and coarser in appearance because it contains coarse, dark granules having a greenish tinge. In recently well-fed animals these granules have a deeper color, more or less bluish green, and the granular appearance is overshadowed by a distinctly alveolar structure. This alveolar appearance is apparently due to the rapid production of a great abundance of food vacuoles, and the greenish coloration would seem to be derived from the chromophyll substance present in the bodies of the vegetable forms of

life ingested by the snail which constitute a portion of the diet of the parasite.

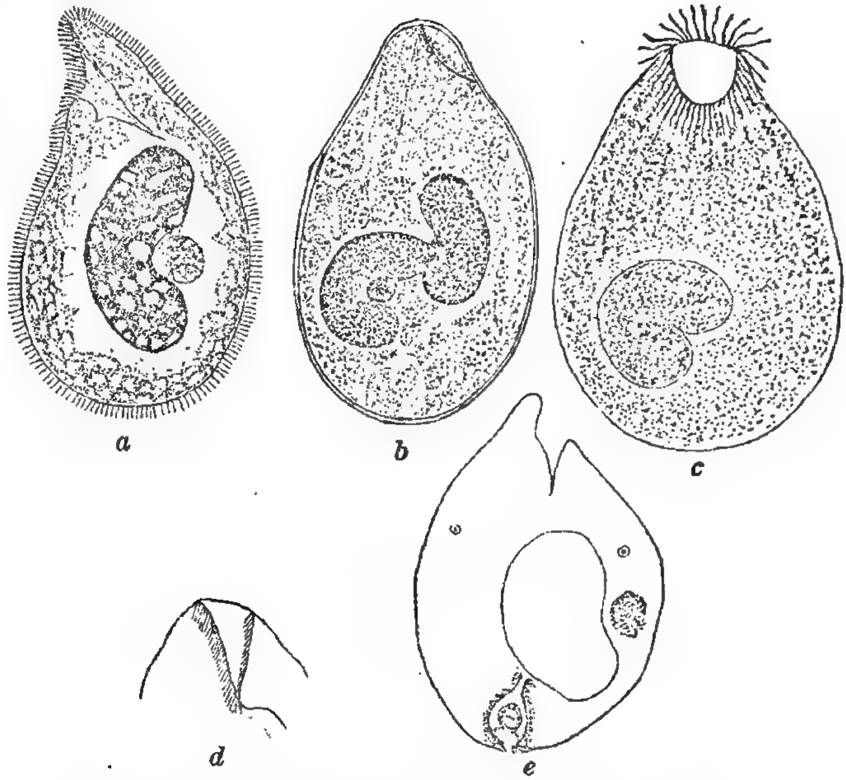

FIG. 1. Oral and excretory apparatus of *Balantidium haughwouti*.

In this portion of the parasite the meganucleus and the micronucleus can be seen, floating and eddying about in most intimate association in the rapid and constant cyclosis of the endoplasm; abundant food vacuoles; fragments of vegetable cells or smaller protozoa, partially digested; and, in some instances, contractile vacuoles. In stained preparations of lean individuals, where the alveolar structure does not obstruct the view, this area is traversed by an intricate system of numerous minute, canal-like structures (see fig. 1, *b*), seen as clear homogenous-appearing lines running through the granular substance. Whether they represent true canals, lines of conduction of excretory products, or are merely artifacts due to unequal shrinkage of protoplasmic elements in the fixing fluid, remains to be determined.

If the former, we should have a condition such as that obtaining in the gregarine-like infusorian *Pycnothrix monocystoides.*

In that organism the endoplasm is traversed by a branching and ramifying system of excretory canals which unite and discharge into a single ciliated efferent duct that opens externally into a pore located at the surface of the body near the posterior end. It should be noted that in *Pycnothrix,* and also in *Opalina,* the excretory systems are endoplasmic, a condition differing from the ordinary cases in the protozoa where the vacuoles are located in the ectoplasm. Both of these forms, however, are nourished by the osmotic method, whereas *Balantidium haughwouti* is holozoic. Furthermore, this balantidium possesses definite contractile vacuoles, which can be seen to pulsate regularly.

In a rapidly moving animal, possibly caused by the pressure resistance of the surrounding medium, the tiny conical papilla already mentioned can be seen with considerable distinctness. The cytopyge (see fig. 1, *e*), as has been said, opens at the tip of this papilla and from it can be seen to issue solid substances and a mucuslike material. Shrinkage in fixation seems to obliterate this papilla, and in the stained preparations the cytopyge only is seen as a minute opening at the posterior extremity. This anal pore is apparently the terminal point of the canal system mentioned in the preceding paragraph, and it is from this that the mucuslike thread is seen to originate.

This, of course, raises the question as to whether there are two distinct systems present; namely, a definite cell anus connected with a canal system providing for the collection and discharge of unused substances taken in by the organism, and a contractile vacuole system of the conventional type which cares solely for the products of catabolism. This is a point I have been unable to determine even by feeding carmine granules to the animals. It is, however, a condition not unknown in the Infusoria.

The contractile vacuoles are seen as one or two well-defined clear spaces just posterior to the meganucleus. Their formation is slow and gradual. They are buoyed to and fro by the cytoplasmic movements and, as they enlarge in volume, appear to migrate to the extreme periphery, approaching the cuticle suddenly to empty their contents through the cuticle to the exterior.

The meganucleus is a conspicuous body lying in the endoplasm. It can be distinguished from the granules and food vacuoles in the living organism by its transparent, homogenous, and colorless appearance. It is flexible to a degree, a characteristic not uncommon in the Infusoria where nuclei such as are seen in the suctorians *Acineta* and *Ephelota* show amœboid contortions.

In stained preparations the meganucleus is the most conspicuous intracellular object. It takes the stain deeply and it is only by good differentiation that its true structure is seen. The shape of this nucleus is quite characteristic. In the vegetative state of the cell its normal form might be said to be sausage-shaped to reniform, but it shows an orderly and progressive series of form changes that develop until it has finally completely curved upon itself to form a circle with the two ends of the nucleus in apposition. The micronucleus is usually lodged in the concavity of the meganucleus and tends to become enclosed by it. The possible significance of these form changes will be discussed later.

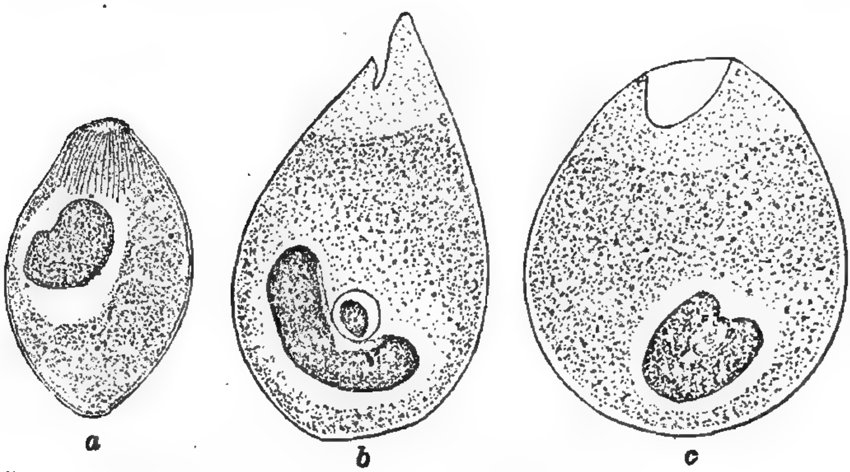

FIG. 2. Cytoplasmic structure and meganuclear and micronuclear relations in *Balantidium haughwouti.*

In stained preparations the meganucleus measures on the average 19.83 μ in length by 7.5 μ in width. In general shape it closely resembles the meganucleus of *Balantidium coli,* and that of *B. entozoön* as figured and described by Stein, who appears to have noticed the same variation in form.

In deeply stained specimens the meganucleus appears to be formed of a solid mass of chromatin. Careful differentiation shows the chromatin to be distributed in the form of fine granules more or less closely packed together. The appearance varies, however, so that the finer structure frequently appears as a reticulum of varying texture. Many nuclei show areas that appear more or less alveolar—that is to say, give the appearance of a network of chromatinic material surrounding clear spaces

or areas of achromatinic substance. The whole is inclosed in a delicate nuclear membrane.

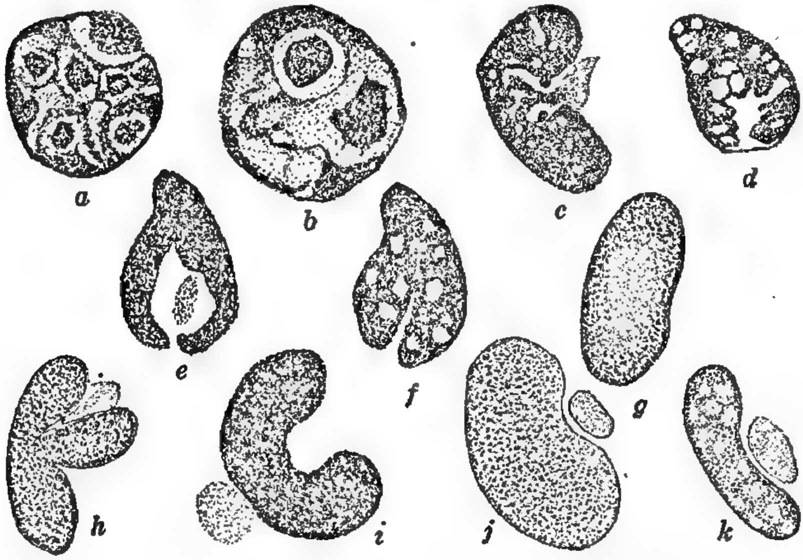

FIG. 3. *a*, *b*, and *c*, Meganuclei of the reticulate type (*a*, superficial; *b*, middle; and *c*, deep focus); *d*, *e*, and *f*, optical sections of a reticulate meganucleus; *g*, meganucleus viewed from its convexity; note the extreme thinness of the "crown" of the nucleus under which lies the micronucleous; *h*, bipartite meganucleus; micronucleus partly shown; *i* and *j*, meganuclei of granular type; *k*, meganucleus of alveolar type.

The finer structure of the meganucleus, as seen in the normal vigorous infusorian, is that of an evenly distributed network of chromatin granules compactly arranged. This structure is, of course, only demonstrable in well-stained and properly extracted preparations. Irregular clumping of the chromatin into a series of groups which gives the appearance of a vacuolated nucleus has been interpreted by various investigators as supervening on unfavorable conditions and as presaging disaster to the organism. I see no support for such a supposition in this instance. All the individuals showing a nucleus of this type were vigorous-appearing cells, exhibiting no signs of the vacuolation and distortion so characteristic of the infusorian cell in distress.

In addition to the regular series of incurving forms, other striking and interesting changes are seen in the structure of the meganucleus. Individuals have been seen in which there were two well-formed meganuclei in the cell. I am inclined to interpret this as, possibly, a result of abnormal distribution of the meganuclear anlagen in the ex-conjugant stage following syngamy, which process, however, I have not observed.

Many cells have been encountered in which the meganuclei have undergone marked changes in shape and appearance. In these cases the nuclei have become spherical or globular and the chromatin is condensed into deeply staining bands or clumps, in the meshes of which is seen clear, achromatinic material. The micronucleus in these cases seems to be sunk deeply into the substance of the meganucleus.

FIG. 4. *a* and *b*, Early stages in inclosure of micronucleus in meganucleus; *c*, later stage.

Other individuals have been seen lacking even a trace of either nucleus, and there are those in which either one or the other nucleus is absent. In such animals there can be seen in the endoplasm fragments of stained substance, possibly of the nature of chromatin, and in one case there was observed (see fig. 5, *c*) a structure which, to all appearances, was the membrane of the meganucleus lacking its chromatin contents. It is impossible at present to arrive at any definite conclusion regarding the real nature of these chromatinic bodies. Walker (12) has described a process of sporulation in *Balantidium falcifarum*, and Stein (10) hints at something of the same nature as occurring in *B. entozoön*. The possibility of endomixis as described by Woodruff and Erdmann must also be borne in mind, but the evidence here is too slight to admit of a discussion of any of these points. The possibility of these bodies being ingested organic matter must likewise be considered. The disappearance of the micronucleus may yet be explained by its incorporation into the meganucleus. Apparent total absence of both nuclei in an uninjured individual is mysterious unless explained on the basis of the fragmentation of both nuclei, or as a result of abnormal division following conjugation.

The micronucleus is a small rounded or elongate body. It is strikingly different in size and structure from that of either *Balantidium coli* or *B. falcifarum*, but most closely resembles Stein's figure of the nuclei of *B. entozoön*. When round it has an average diameter of 3.3 μ, but when elongated it measures 6.88 μ by 4.22 μ. It seems likely that the normal shape is spher-

ical and that the elongation and the consequent increase in size are early evidence of beginning nuclear division.

This nucleus is invested with a delicate nuclear membrane very difficult to demonstrate. There appears to be a cortical layer of homogenous transparent material that stains very lightly with the nuclear stains. In the gross, it appears to be practically a structureless body. Carefully differentiated spec-

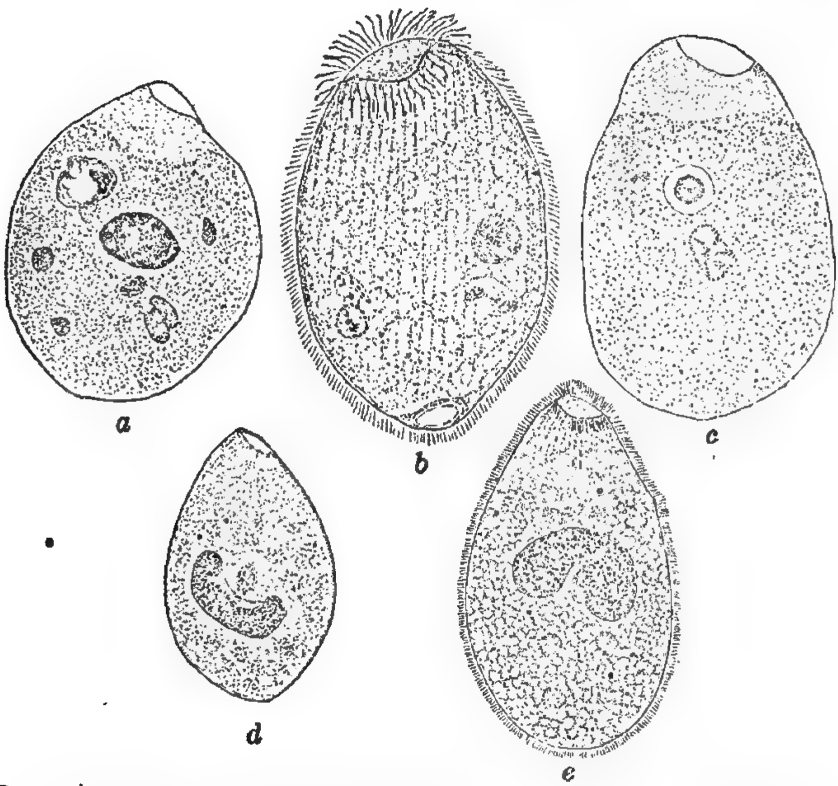

FIG. 5. *a*, A small meganucleus is present; the micronucleus seems to have fragmented; *b*, the meganucleus and its membrane have disappeared; the cytoplasm contains chromatinic bodies of unknown nature; *c*, the meganucleus has disappeared leaving a body that appears to be its membrane; the micronucleus appears in a distinct capsule; *d* and *e*, early and late stages showing the incurvation of the meganucleus about the micronucleus.

imens show, however, that within this achromatinic cortical layer there lies a minute chromatinic granule, or a collection of granules irregularly distributed on a reticulum. This heavy achromatinic cortex is not present in the micronucleus of either *Balantidium coli* or *B. falcifarum.*

It is a little difficult to determine how much of this "cortex" is plastinoid substance or how much of it represents nuclear

sap. The single granule would appear to be in the nature of an endosome floating free in a sac containing nuclear sap and, possibly, plastin. In well-differentiated specimens there appears to be an inlying achromatinic network upon which, in many cases, are distributed chromatinic granules. These granules do not appear in all nuclei and their presence may betoken impending nuclear division.

The normal position of the micronucleus is at the concavity of the meganucleus where it fits very nicely and where the meganucleus eventually encloses it within its folds. At times it can be seen well sunk in the notch, and at other times it is lying only on the edge. It may wander out of the meganuclear notch (see fig. 3, *i*) and be found anywhere near the meganucleus or completely separated from it and floating alone in the endoplasm.

Although there is good ground for believing that this animal forms cysts, I have been unable to identify any of them with certainty. Apparently they occur rarely or not at all in the intestinal contents and it seems likely that, after a brief free-swimming stage in the pond water, the ciliates round out and form cysts which settle on aquatic plants to be later taken in by other snails. In other words, apparently the conditions in the intestines of the host as regards food supply are sufficiently favorable to preclude the formation of cysts there in the general run of infections.

Outside of the snail the animals die quickly under experimental conditions. Under natural conditions it is possible that encystation takes place exogenously as has been suggested.

The question of the exogenous life of *Balantidium* is of some interest from the viewpoint of preventive medicine. As regards *Balantidium coli* several observers have reported it as occurring free. Kleine(7) states that he never failed to find "Paramecium coli" or *Trichomonas* in the sewage as it passed out of St. Bartholomew's Hospital, London. He adds that if he wanted to obtain numerous specimens of these organisms all that was necessary was to bottle specimens of the highly diluted sewage and keep them for a period of about three weeks, after which abundant organisms were available.

Such an observation as this requires careful confirmation. In the first place, it practically presupposes an instance of *Balantidium* infections out of all proportion to those that have been reported. It seems highly probable here that Kleine mistook other members of the family Bursaridæ for *Balantidium*. Conn(1) with some reservation has reported *Balantidium coli* as

occurring free in fresh waters in Connecticut, in the United States, but he says nothing regarding the possible source of the parasites. Haughwout(5) has briefly discussed the matter of a free-living stage in the life cycle of *Trichomonas* and raised a question as to the identity of the organisms described by several authors as occurring free.

METHOD OF FEEDING

These animals are very voracious, continuing to feed, under the cover glass, almost up to the time of death. When feeding they move slowly and evenly forward, producing, by means of the adoral membranelles, a powerful current of water near the anterior end. This current simulates a whirlpool, the vertex of which points toward the oral depression. It is produced by the coördinated succession of rapid lashing movements of the membranelles and cilia from without oralward. This movement produces to the eye the effect of a rotating peristome or the trochal disk of a rotifer. The current of water impinges on the oral vestibule at an effective angle at one side. There is a sideflow which leaves the depression on the opposite side much as is seen in the case of *Vorticella.* There apparently is little, if any, choice of food at the intaking—every object below a certain size is swept into the pharynx; the rest goes out in the sideflow. Such selection as there is must be rapid, judging from the rapidity of the inward and outward flow of water from the oral cavity. It would seem that selection is governed more by the size of particles taken into the oral opening than by the quality.

THE RELATION BETWEEN THE MEGANUCLEUS AND THE MICRONUCLEUS

This relation presents one of the most interesting features for future work with this species. It is unfortunate that out of many hundreds of individuals studied not one has been seen in division, and no conjugating pairs have been found.

The enclosure of the micronucleus within the meganucleus is too regular in its occurrence to be accidental, or without significance of some kind. Two possibilities suggest themselves: Either it represents a type of nuclear division of a rather new and remarkable kind, or it represents a process of nuclear reorganization perhaps along the line of endomixis. Unfortunately the picture so far presented is too incomplete to admit of definite conclusions regarding either supposition. There is also the added handicap of incomplete knowledge of division phases of the micronucleus.

As a rule, in dividing cells of the Ciliata, the micronuclei divide first by mitosis, division of the meganucleus which comes later being of a direct type often, apparently, in the nature of a more or less mechanical partition of the chromatin.

In the case of *Boveria subcylindrica*, a more or less aberrant genus but with close affinities to the Heterotrichida, as described by Stevens(11), the relation between the meganucleus and the micronucleus at division of the former is much more intimate. At division the micronucleus comes to lie in contact with the meganuclear membrane. The spindle appears usually at one side, but near the posterior end of the meganucleus. Later it stretches along the nuclear membrane with its poles approaching the ends of the meganucleus. The two micronuclei when separated are located at or very near the poles of the dividing meganucleus. It would seem clearly indicated from this that the micronucleus wields a distinct influence over division of the meganucleus, a much more direct influence than is shown in Ciliates generally.

Ikeda and Ozaki(6) have recently described another interesting relation between the mega- and micronuclei of *Boveria labialis*, a new species occurring in the respiratory trees of two Japanese holothurians. Unfortunately, I have been unable to obtain the original paper and have only seen it in abstract. The phenomenon was observed in conjugation. Following zygosis, the synkaryon divides twice. One of these daughter nuclei becomes the micronucleus of the reorganized individual. The other three products of this division undergo degenerative changes and become incorporated into the persisting meganucleus and may be traced in the first and second fissions of the exconjugant boverias.

This merely gives a possible clue to what is going on in this species of Balantidium. It seems possible, and indeed is suggested by some of the figures, that the micronucleus in its incorporation into the meganucleus may come to function as a division center within the substance of the meganucleus, separating out and resuming its identity at the conclusion of the process. In a way this would merely constitute a variation in the process described by Miss Stevens. As to my observation that this constitutes a post-conjugation phenomenon, that must be laid aside, for the present, for the reason that no earlier stages of conjugation have been seen.

Several other interesting cytological points in this species need clearing up, but they must be left for future work.

Another subject for future investigation lies in the determination of the ability of *Balantidium haughwouti* to live in a host other than *Ampullaria.* This is important by reason of the fact that the host is frequently eaten by persons living in the Philippine Islands. As has been stated, it shows no tendency to penetrate the tissues of the host within which it has been studied, but that is no criterion of what it might do in another host. At the same time it would seem that the danger of infection in man by this parasite is rather remote, if for no other reason than that the character of the food it receives in the gut of the *Ampullaria* is such as would involve a rather revolutionary readjustment of the parasite's metabolism on adaptation to a life in the tissues of man.

In conclusion, I desire to designate this species *Balantidium haughwouti* in compliment to the man who first observed it.

CONCLUSIONS

The characters possessed by this organism indicate its inclusion in the genus *Balantidium.*

Further work is needed to determine definitely the functions of the cytopyge and of the excretory systems.

It is also in order to determine if there is any neuromotor apparatus.

A close relation is shown between the meganucleus and the micronucleus. For the present it is assumed that this has to do with division.

Stained preparations of *Balantidium haughwouti* together with shells of the snail *Ampullaria* from which they were taken have been deposited in the protozoölogical collection at the Bureau of Science, Manila, and at the Smithsonian Institution in Washington D. C.

ACKNOWLEDGMENTS

To Prof. Frank G. Haughwout, chief of the department of parasitology, at whose instance this study was undertaken, I wish particularly to express my appreciation of the stimulating and material help and encouragement given me throughout the course of the work. I wish to thank Prof. Sol F. Light, who identified the snail host; Dr. Lamberto Leiva for material help; and Prof. Ricardo Fernandez for assistance in translating from the French literature. For permission to undertake this work in another department while a member of the staff of the de-

partment of obstetrics appreciation is due to Dr. Fernando Calderon, chief of the department, and for opportunity to complete it since my transfer to the department of pathology and bacteriology, to Dr. H. W. Wade.

REFERENCES

1. CONN, H. W. A Preliminary Report on the Protozoa of the Fresh Waters of Connecticut. Hartford Press, Hartford, Conn. (1905) 56.
2. DOBELL, C. Cytological studies on three species of ameba—A. lacertae Hartman, A. glebae n. sp., A. fluvialis n. sp. *Arch. f. Protistenk.* 34 (1914) 142.
3. FANTHAM, H. B., STEPHENS, J. W., and THEOBALD, F. V. The Animal Parasites of Man. London, John Bale, Sons and Danielsson Ltd. (1916) 201.
4. FAURE-FREMIET, E. L'Ancystropodium maupasi (n. gen., n. sp.). *Arch. f. Protistenk.* 13 (1909) 121.
5. HAUGHWOUT, F. G. The tissue-invasive powers of the flagellated and ciliated Protozoa with special reference to Trichomonas intestinalis. A critical review. *Philip. Journ. Sci.* § B 13 (1918) 217.
6. IKEDA, I., and OZAKI, Y. Journ. Coll. Sc., Imp. Univ., Tokyo, 40 (1918) art. 6. Reviewed in Nature 102 (1918) 95.
7. KLEINE, E. Paramæcium coli and Trichomonas in sewage. *Brit. Med. Journ.* 2 (1896) 1852.
8. SANGIORGI, G., and UGDULENA, G. Ciliati nell' intestino umano. *Pathologica* 9 (1917) 1.
9. SAVILLE-KENT, W. A Manual of the Infusoria. London, David Bogue (1881–1882) 579.
10. Cited by STEIN, F. Der Organismus der Infusionsthiere. Wilhelm Engelmann. Leipzig 2 (1867) 309.
11. STEVENS, NETTIE M. Further studies on the ciliate infusoria Lichnophora and Boveria. *Arch. f. Protistenk.* 3 (1904) 1.
12. WALKER, E. L. Sporulation in the parasitic ciliata. *Arch. f. Protistenk.* 17 (1909) 296.
13. WATSON, M. E. A new infusorian parasite in sand fleas. *Journ. Parasitol.* 2 (1916) 145.

ILLUSTRATIONS

PLATE I

Balantidium haughwouti sp. nov.

TEXT FIGURES

FIG. 1. Oral and excretory apparatus of *Balantidium haughwouti.*

2. Cytoplasmic structure and meganuclear and micronuclear relations in *Balantidium haughwouti.*

3. *a*, *b*, and *c*, Meganuclei of the reticulate type (*a*, superficial; *b*, middle; and *c*, deep focus); *d*, *e*, and *f*, optical sections of a reticulate meganucleus; *g*, meganucleus viewed from its convexity; note the extreme thinness of the "crown" of the nucleus under which lies the micronucleus; *h*, bipartite meganucleus; micronucleus partly shown; *i* and *j*, meganuclei of granular type; *k*, meganucleus of alveolar type.

4. *a* and *b*, Early stages in inclosure of micronucleus in meganucleus; *c*, later stage.

5. *a*, A small meganucleus is present; the micronucleus seems to have fragmented; *b*, the meganucleus and its membrane have disappeared; the cytoplasm contains chromatinic bodies of unknown nature; *c*, the meganucleus has disappeared leaving a body that appears to be its membrane; the micronucleus appears in a distinct capsule; *d* and *e*, early and late stages showing the incurvation of the meganucleus about the micronucleus.

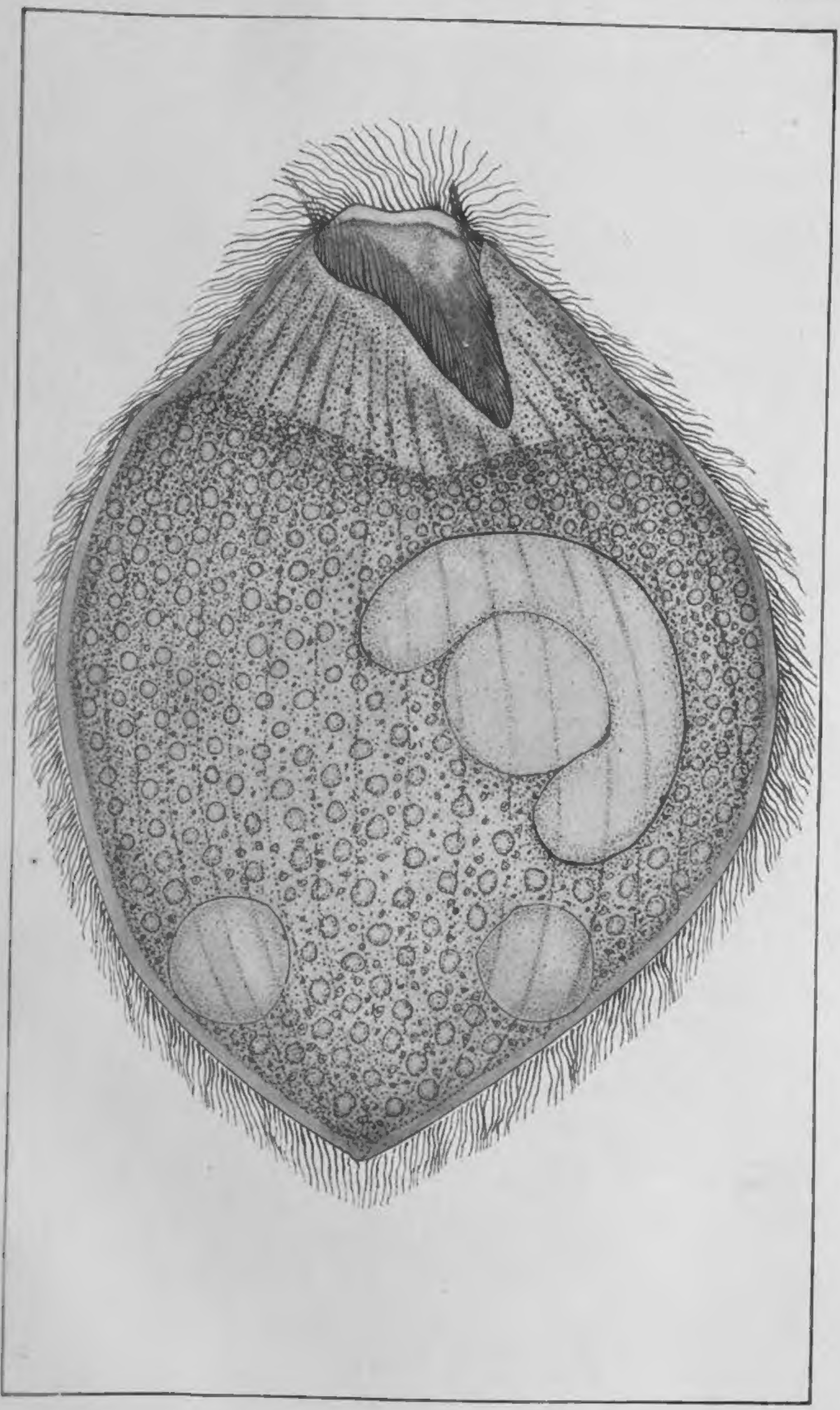

PLATE I. BALANTIDIUM HAUGWOUTI SP. NOV.

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CONTENTS

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